Signals and Systems

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0. Preface

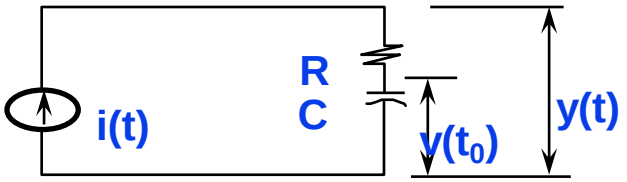
- Engineer Modeling
- Signals & Systems
  - Examples
  - Definition
- Historical Perceptive
  - Engineering Discovery
  - Digital Environments
- Contents
  - Discussed Topics & Textbooks
  - Outline & Time Scheduling

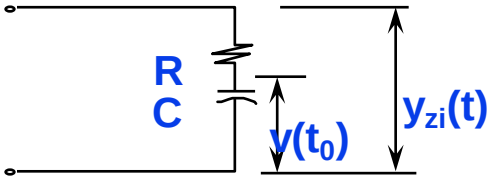
0. Preface

- Related Courses in NCTU
  - Mathematics
  - Advanced Courses & Applications
- Requirements
  - Presentation & Discussions
  - Homeworks and Matlab
  - Three Examinations
  - Score Decision

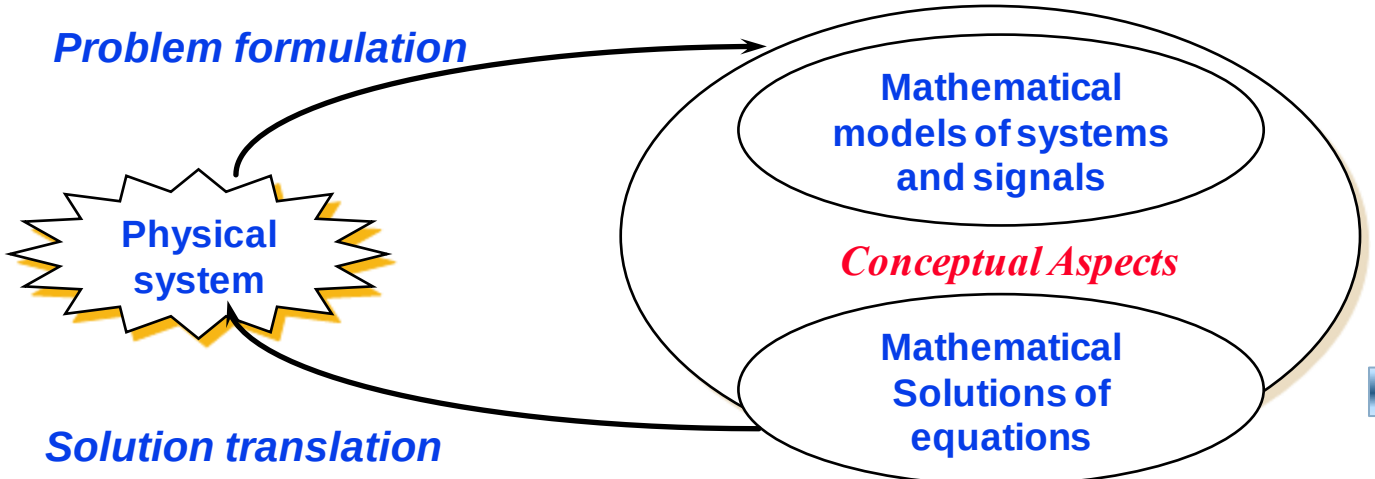
0.1 Modeling

- Two distinct engineer modeling
  - Physical systems are modeled by *mathematical equations.*
  - Physical signals are modeled by *mathematical functions*.





$$y(t) = Ri(t) + \frac{1}{C}\int_{t_0}^{t} i(\tau)\,d\tau + v(t_0)$$



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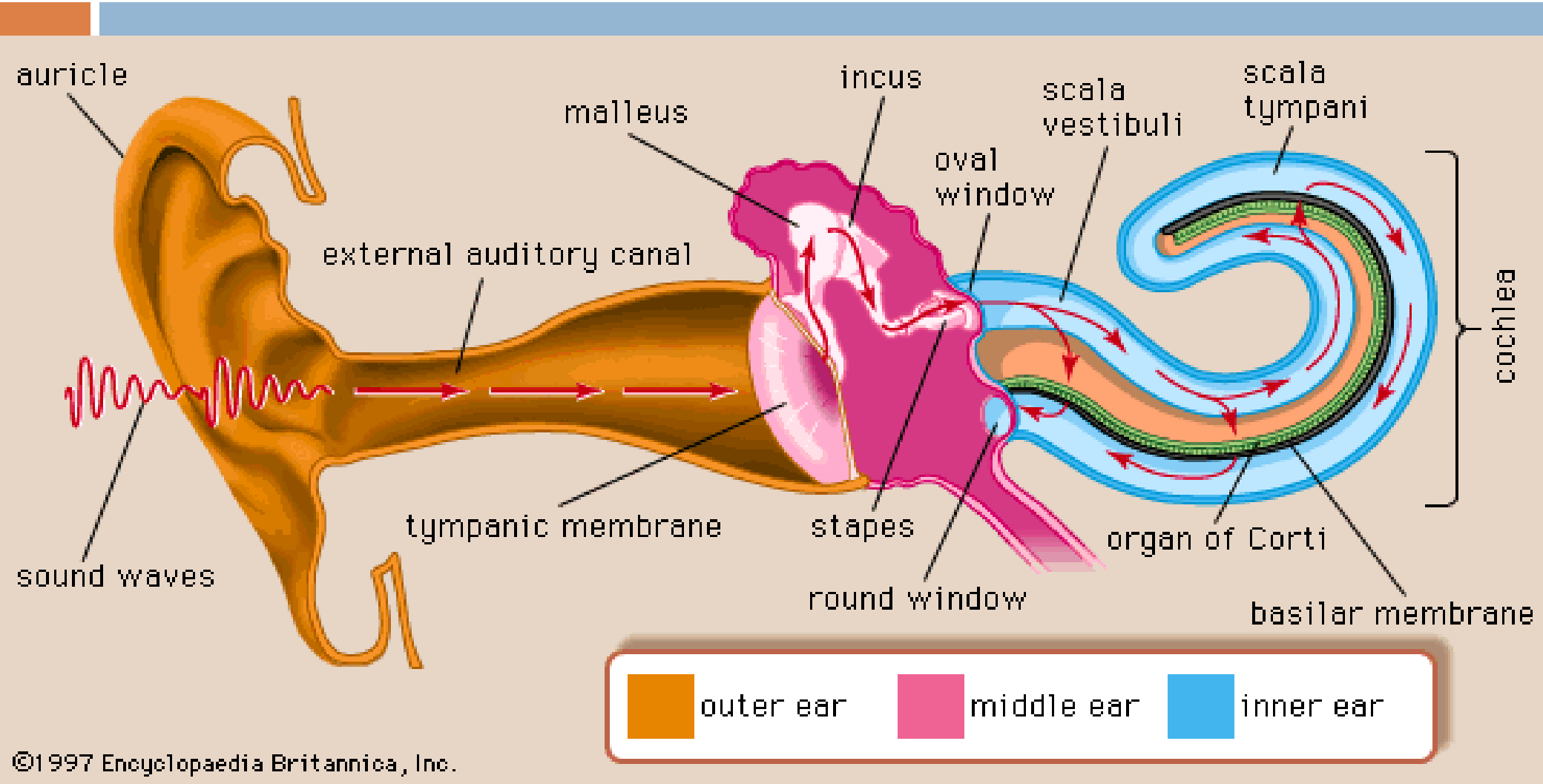
Ear Functioning: Hearing



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Structures of the ear

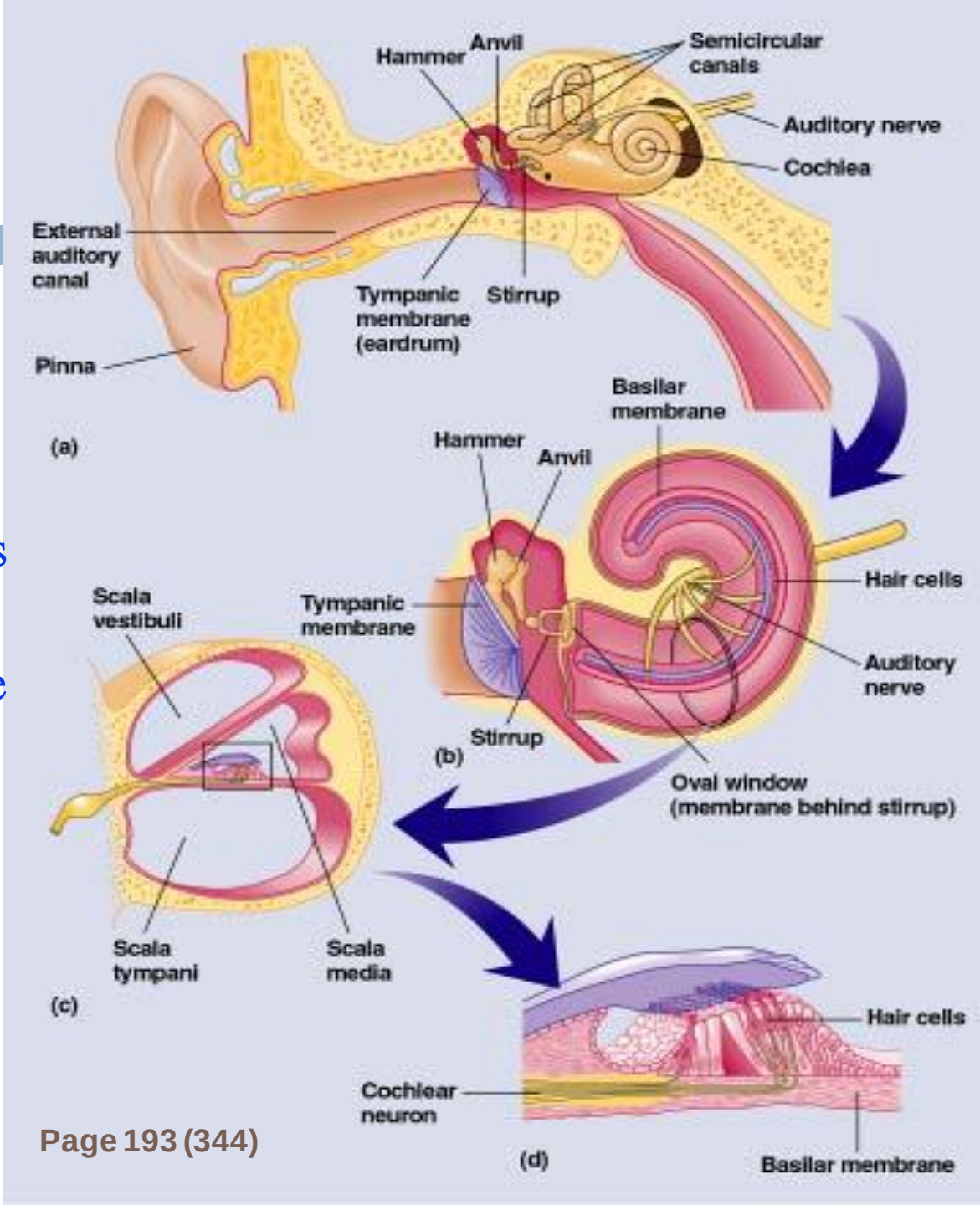
The *pinnae* help collect the sound, but are also somewhat directionally sensitive (much more so in dogs, bats and other animals)

The ear canal actually amplifies frequencies of 2000-5000 Hz due to *resonance*.

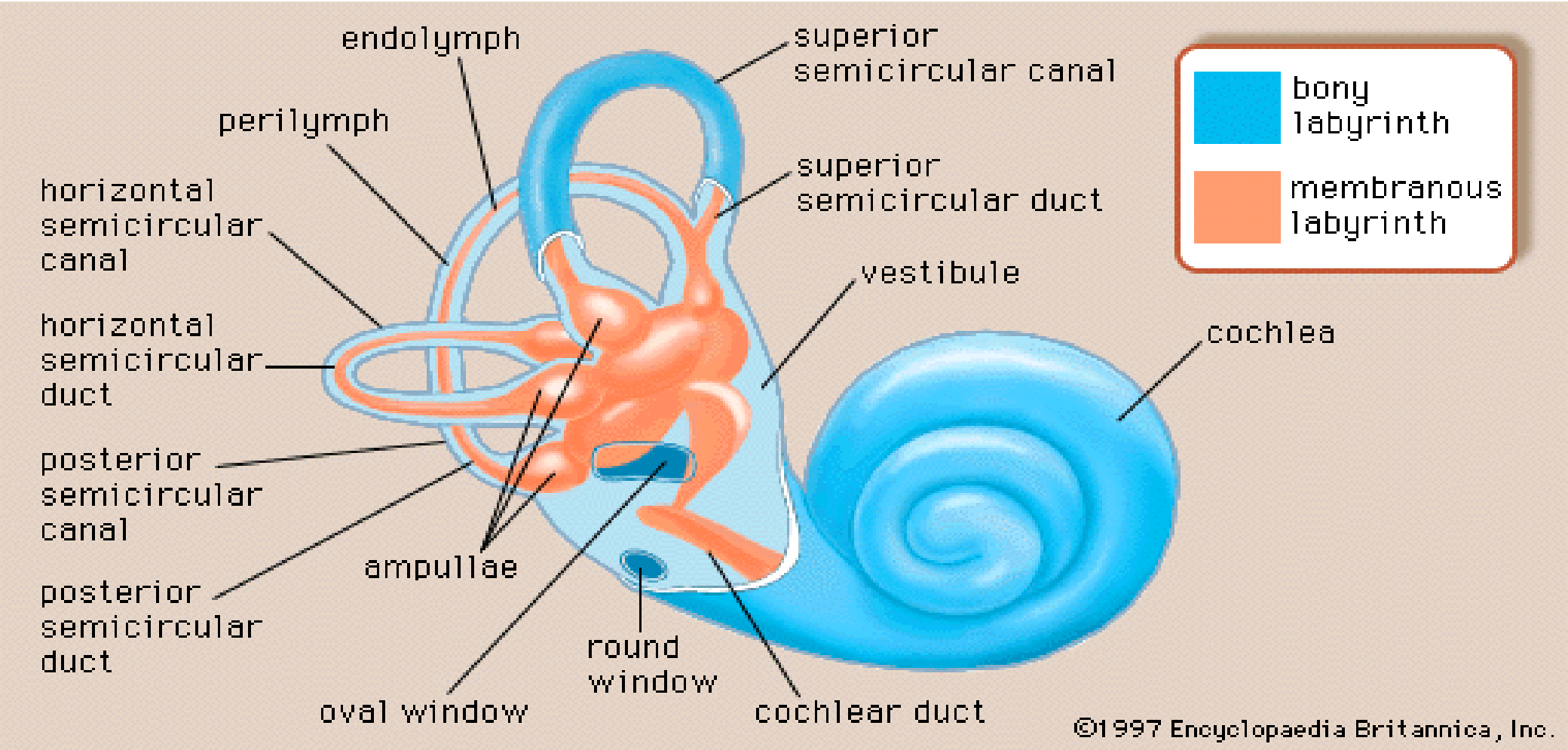
The middle ear is filled with air through the *Eustachian tubes* which open in the throat.

The *ossicles* of the middle ear amplify the pressure waves through lever action and by concentration (the oval window is 15x smaller than the eardrum.

Tiny muscles on these bones reflex-ively contract in response to very high pressures, preventing cochlear damage



Inner Ear: Vestibule, Canals, Cochlea



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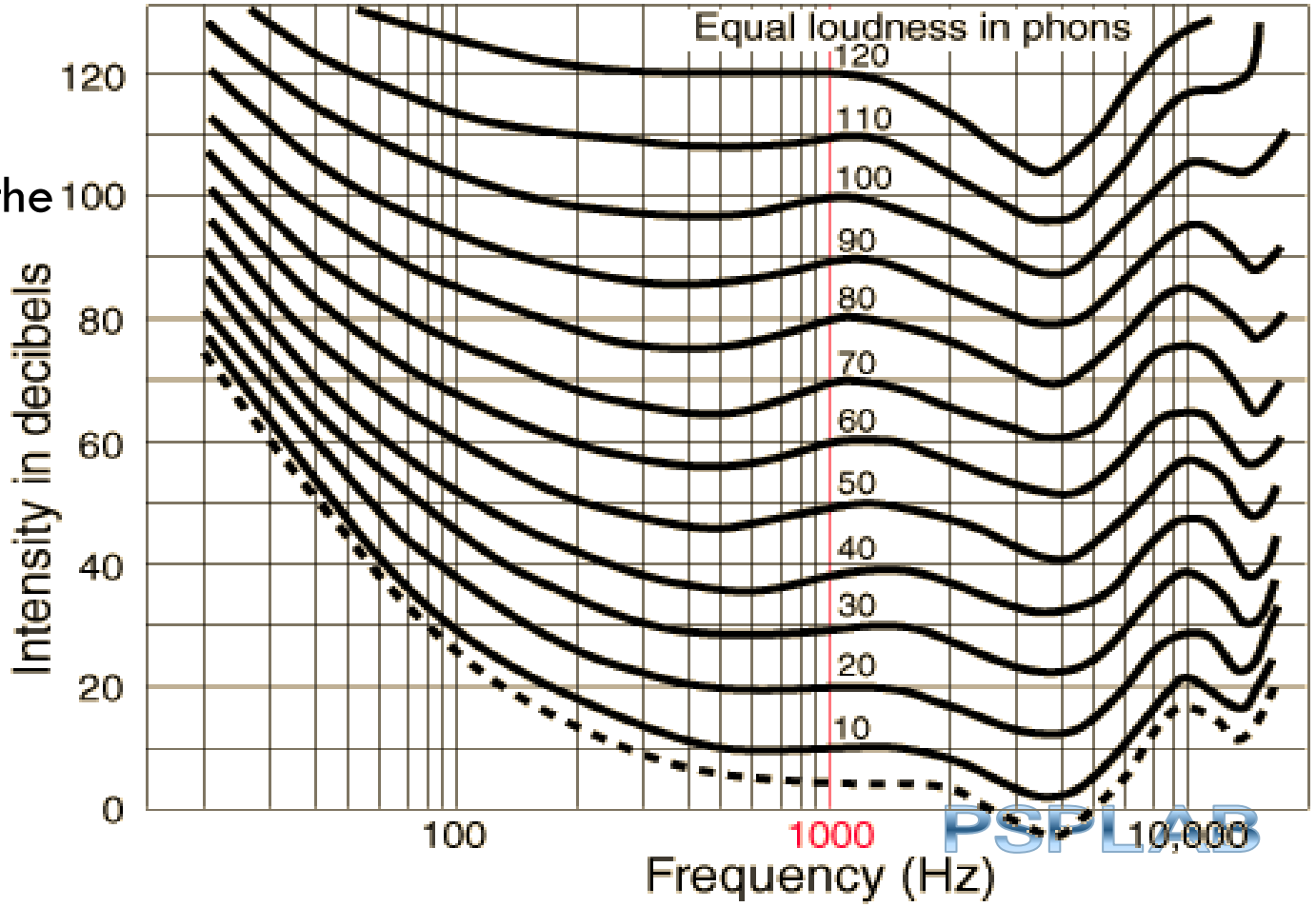
Equal Loudness Curves

- Two different 60 decibel sounds will not in general have the same loudness
  - equal intensity is not the same thing as equal loudness.

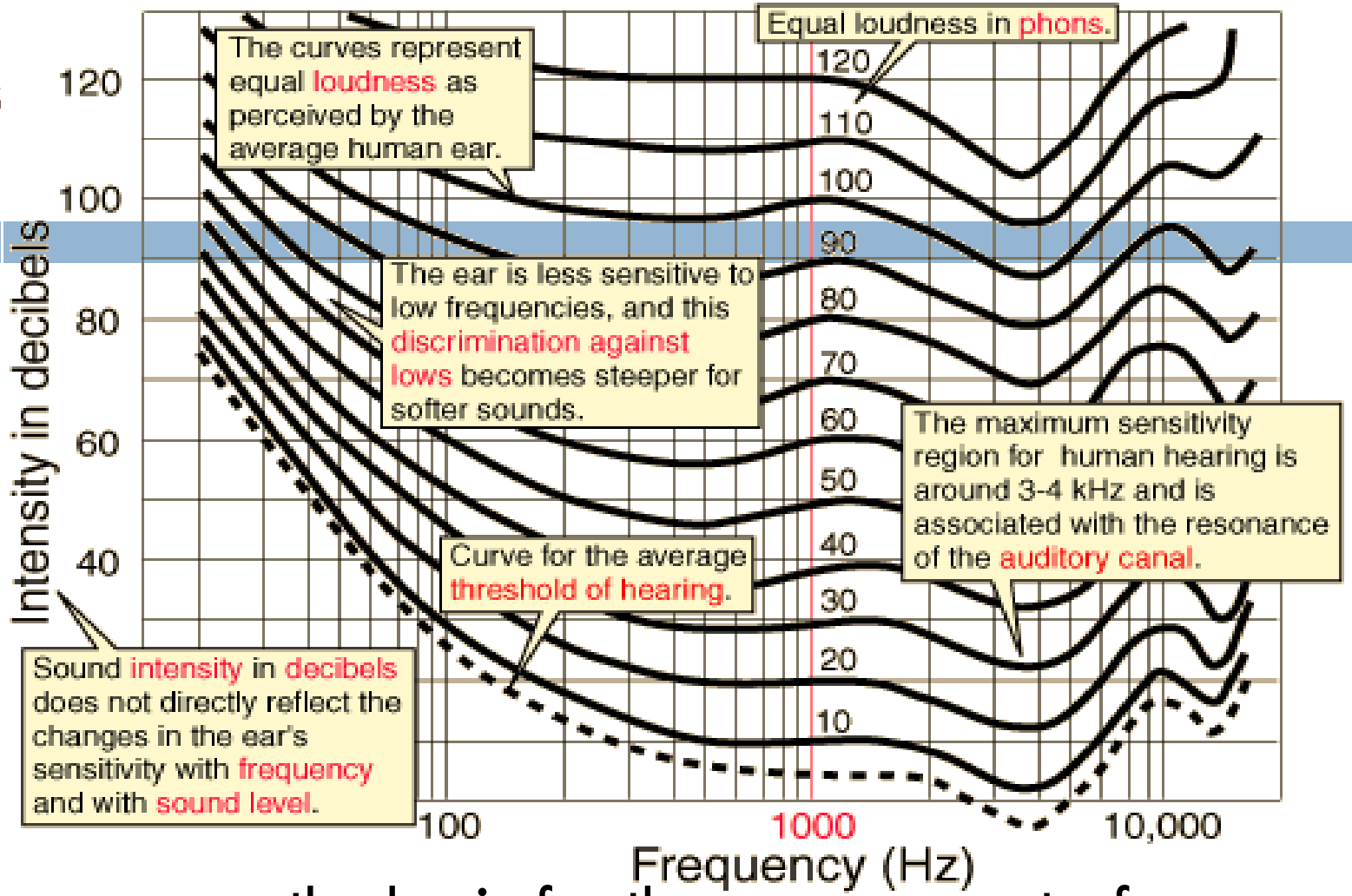
Since the human hearing sensitivity varies with frequency, it is useful to plot equal loudness curves which show that variation for the average human ear.



Equal Loudness Curves

(with labels)

- Source: http://hyperphysics.phy-astr.gsu.edu/hbase/sound/phon.html#c1



- Qual loudness curves are the basis for the measurement of loudness in ***phons***.
  - If a given sound is perceived to be as loud as a 60 dB sound at 1000 Hz, then it is said to have a loudness of 60 phons.
  - 60 phons means "as loud as a 60 dB, 1000 Hz tone"

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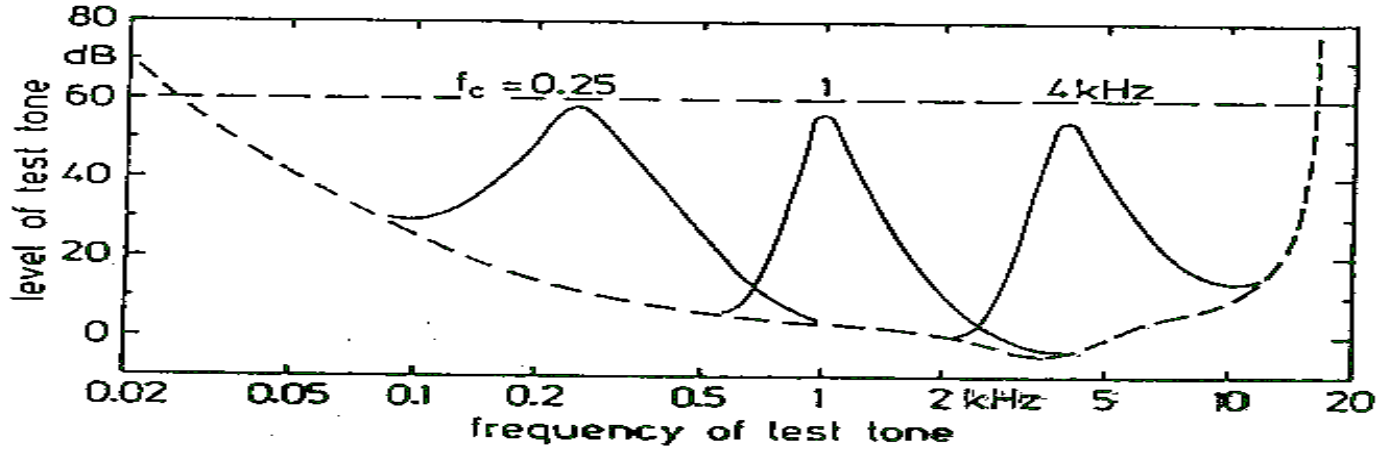
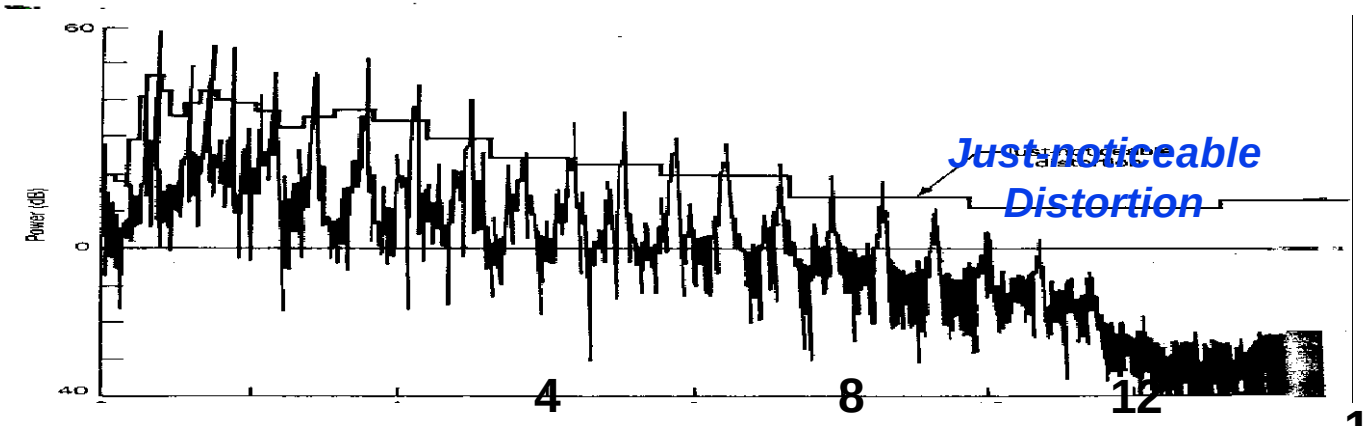
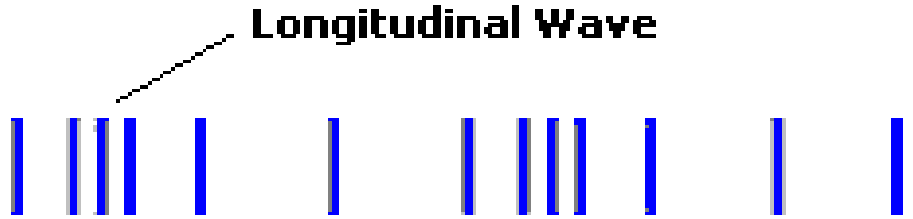
0.2 Signals & Systems: Audio Example (c.2)

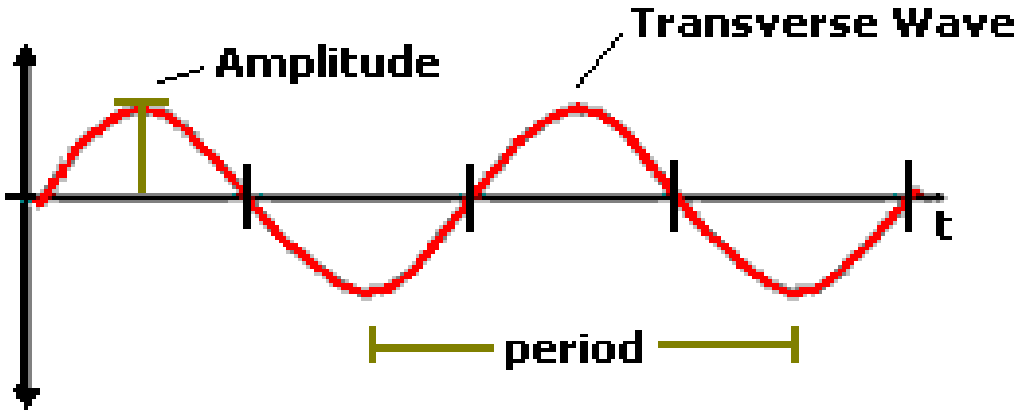
- Psychoacoustic Modeling (c.1)
  - 

  - 

The Nature of Sound



Sound as mechanical wave energy requires a medium such as air or water in which to move.



Sound: vibratory energy caused by movement of physical objects

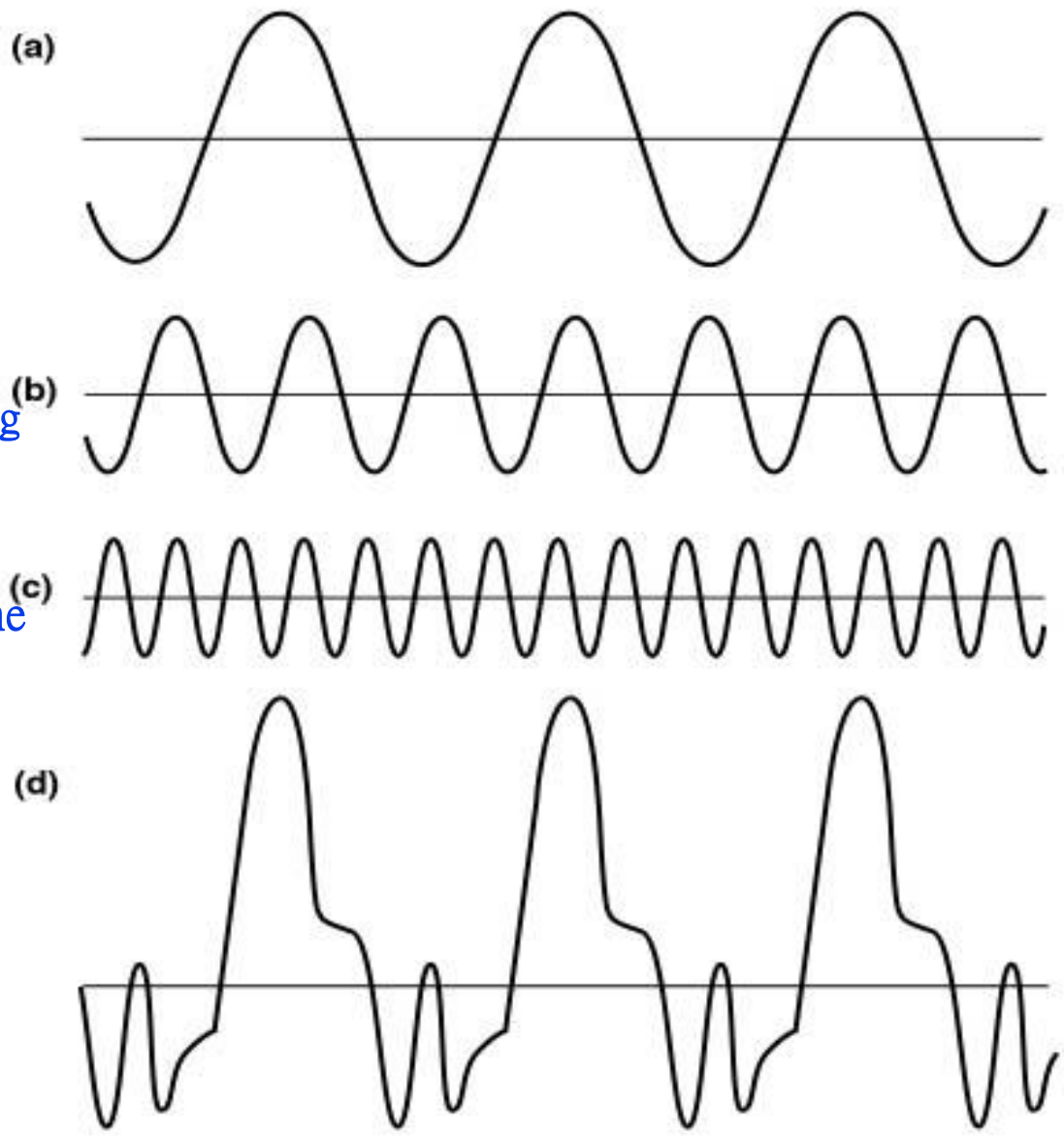
- Rate of vibration is called **frequency**
  - What we hear is **pitch** (high or low)
  - We hear 20-20,000 Hz (cycles/sec)
- Size (intensity) of vibration is **amplitude**
  - What we experience is loudness
  - Measured in **decibels** (dB) (too loud too long = hearing loss)

Figure 10.7, page 338

Additive synthesis & Fourier analysis

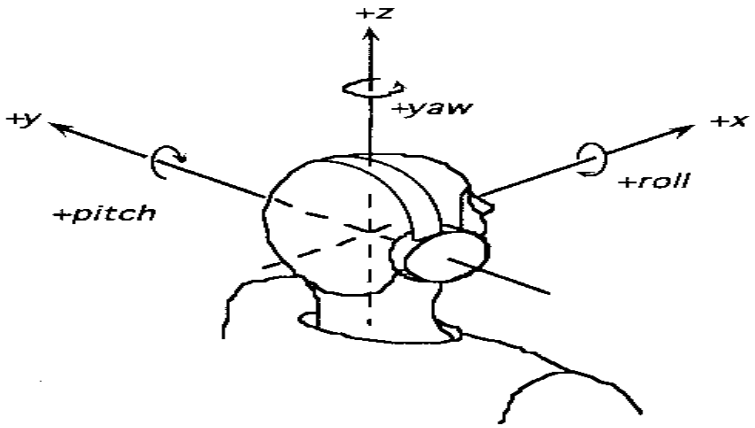
As in Fourier analysis of patterns of light, the same method can be used for representing and constructing complex sound wave phenomena.

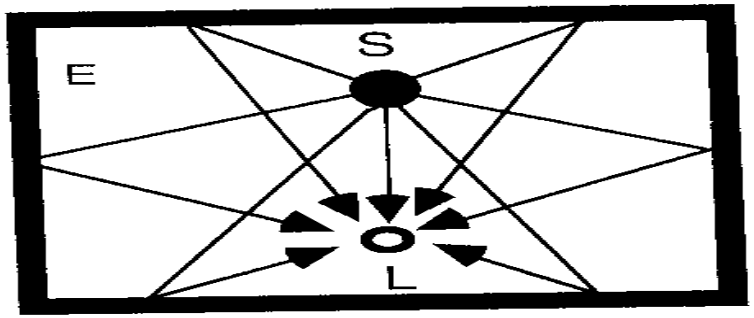
Here (d) is a composite of the fundamental (a) plus its second and third harmonics, (b) and (c).



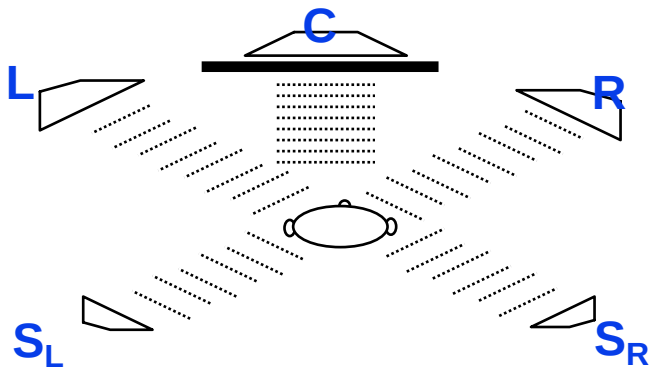
0.2 Signals & Systems: Audio Example (c.3)

- Spatial Information





- Applications
  - Audio Compression
  - 3D Sounds
  - Music Synthesis



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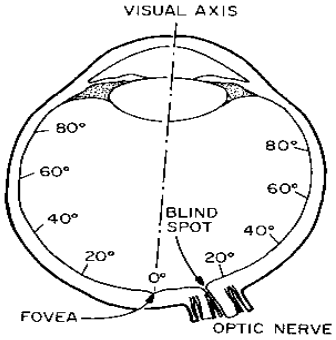
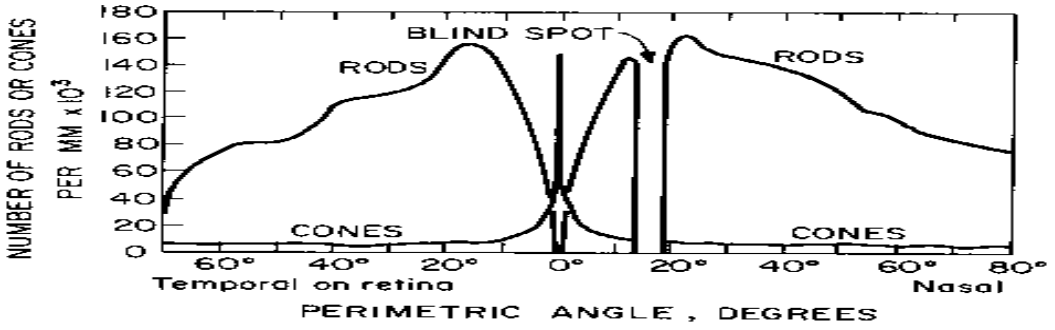
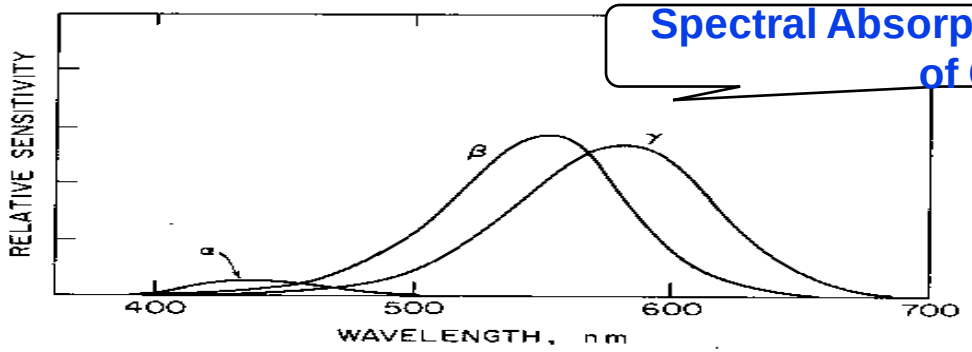
0.2 Signals & Systems: Visual Example

- Psychovisual Modeling
  - Eye Structure
  - Color Information







Spectral Absorption of Three Types of Cones

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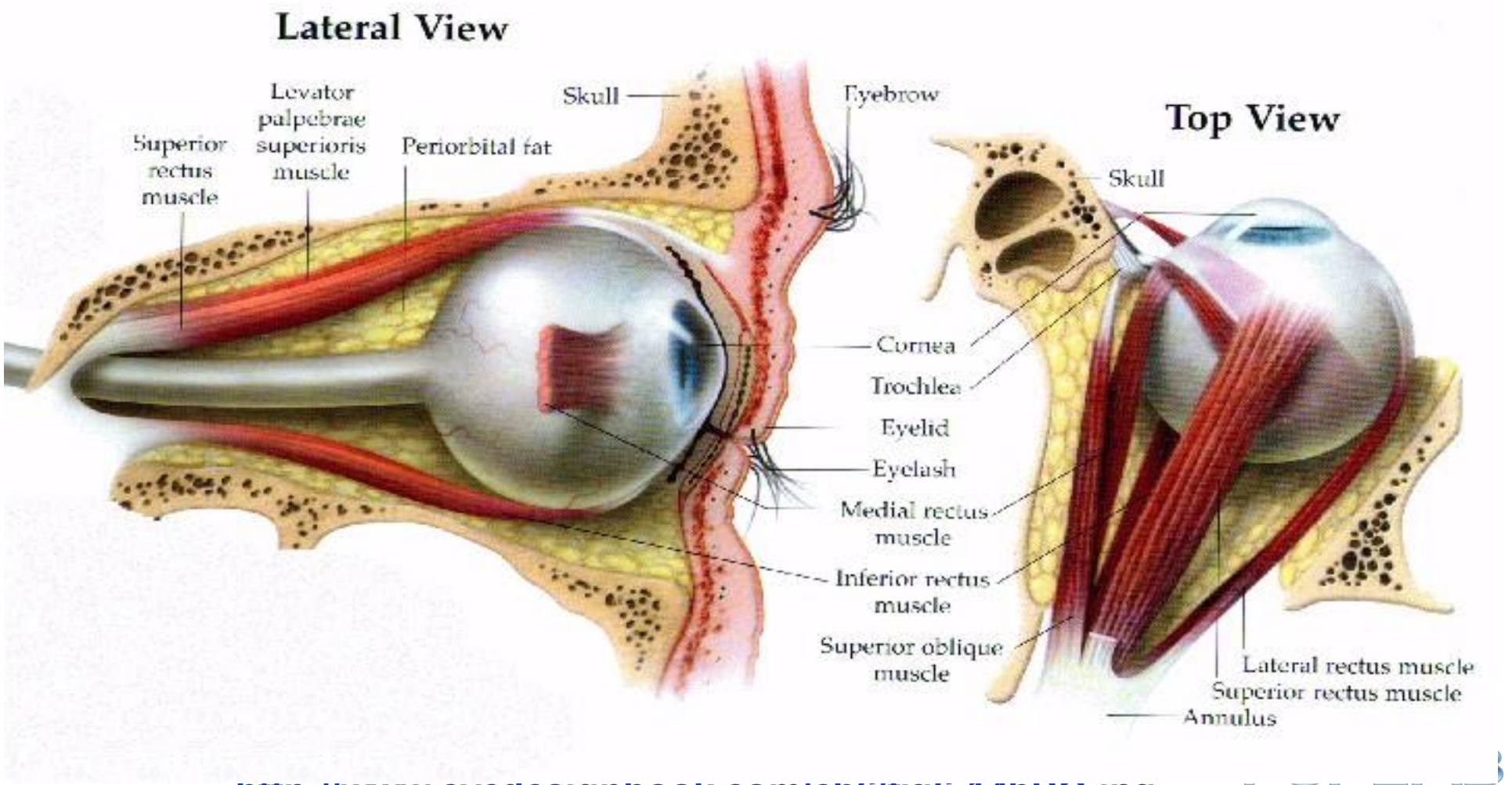
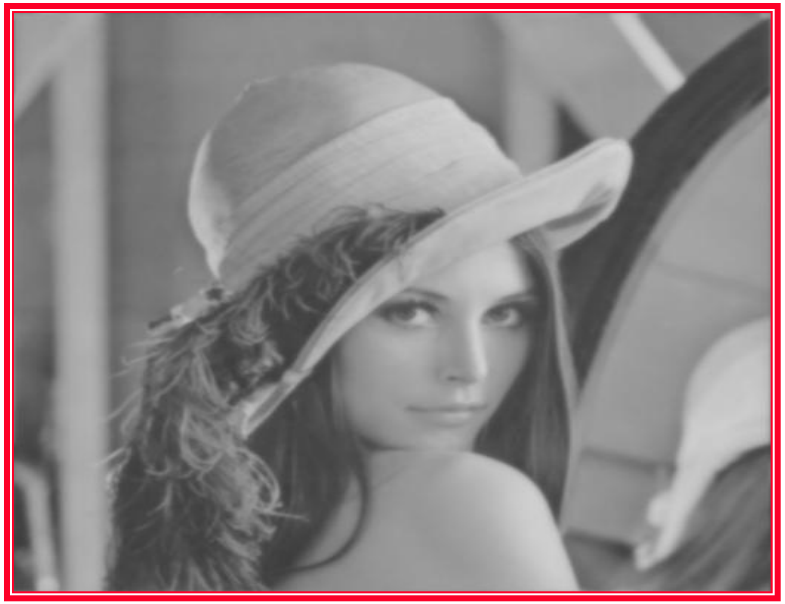
The Human Eye



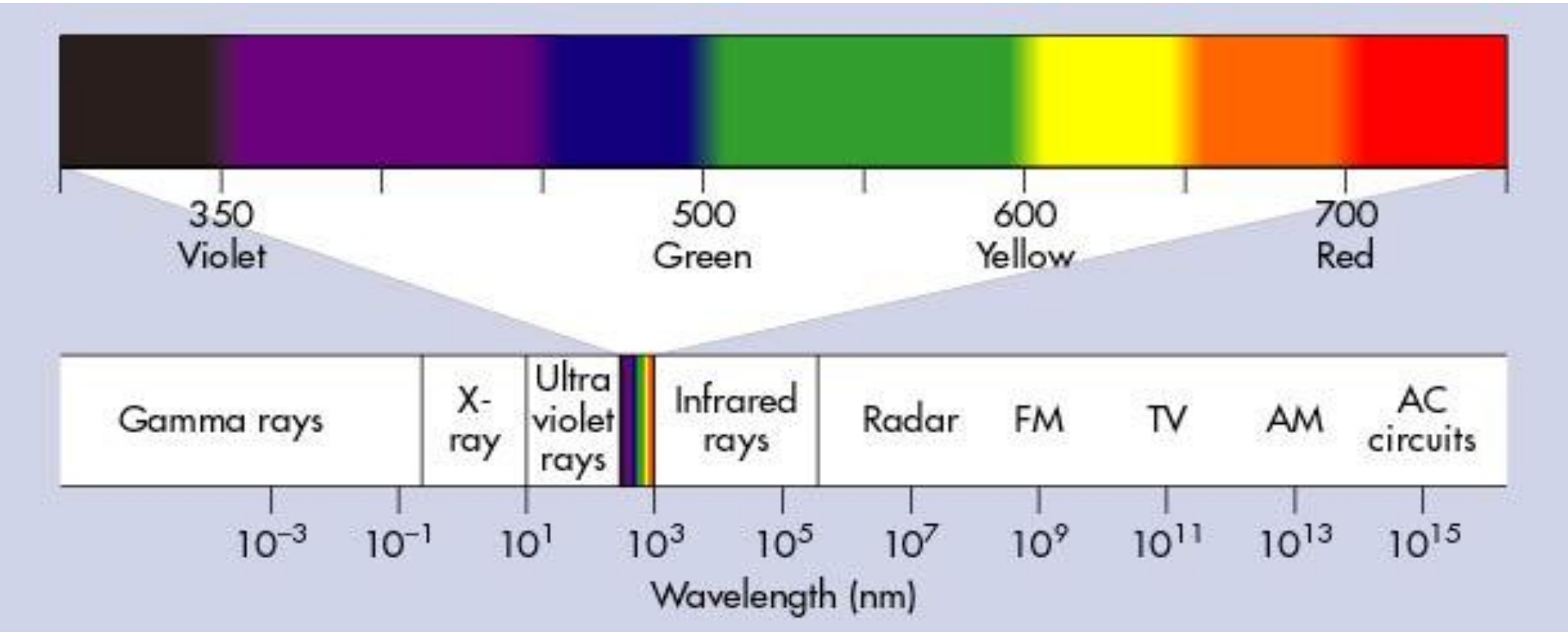
http://www.eyedesignbook.com/ch6/fig6-14bBG.jpg

0.2 Signals & Systems: Visual Example

- Image blurring Systems



A beam of light separated into its Wavelengths



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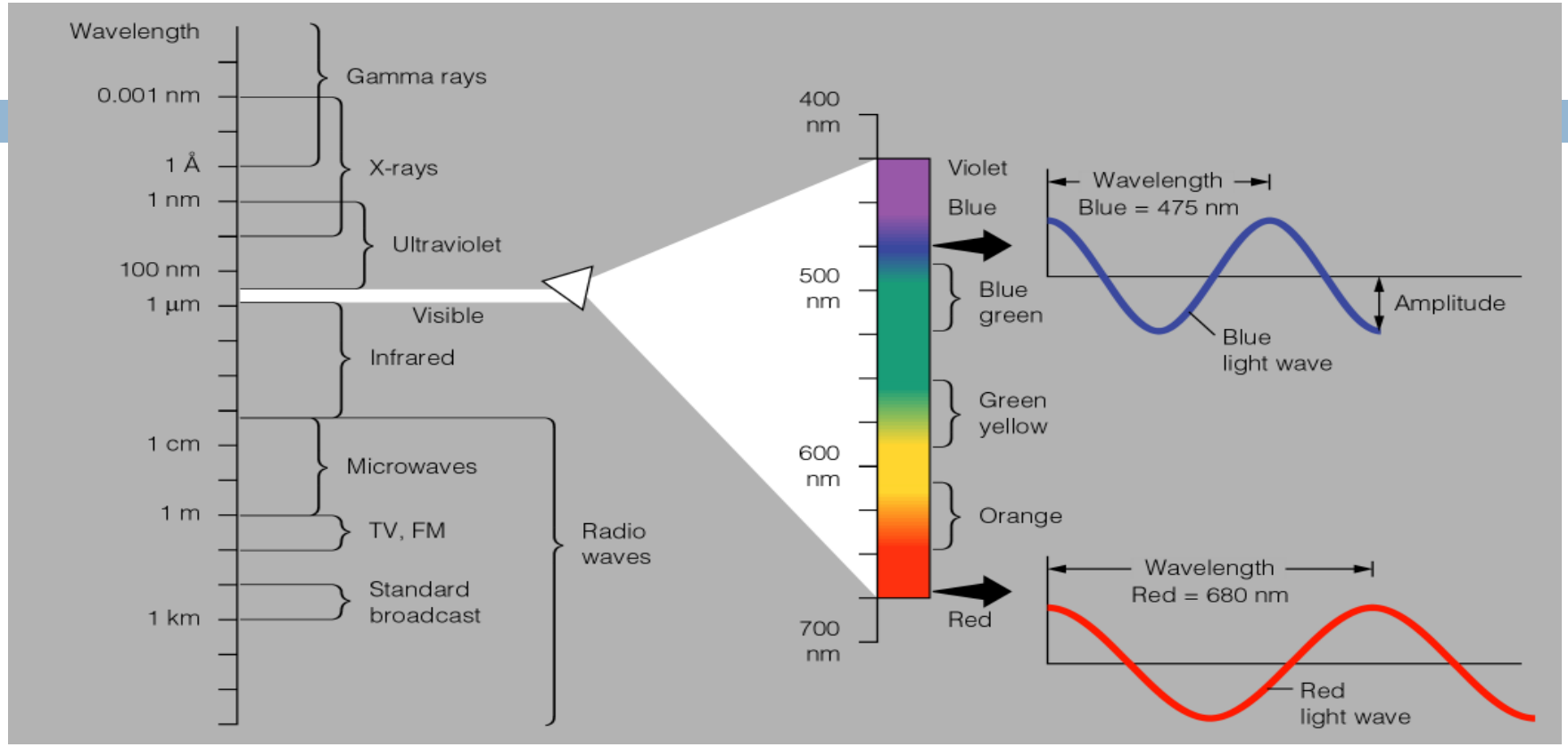
The Electromagnetic Spectrum



Colour is a "secondary" quality, a relation between light entering eye and brain function, a construct of the mind, not a quality in objects (not a "primary quality")

Primary qualities are quantifiable, mathematical, external.

Galileo (1623) The book of Nature "*is written in language of mathematics*"

Newton (1721): "*For the rays, to speak properly, are not colored*."

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0.2 Signals & Systems: Definition

- Signals
  - Functions of one or two variables.
  - Typically contain information about the behavior or nature of some phenomenon.
- Systems
  - Respond to particular signals by producing other signals.
- Example 1: Electrical Circuits
  - Signals: Voltage and Currents as a function of time in a electrical circuit are examples of signals.
  - Systems: The circuit is a system.
- Example 2: Automobile Driver
  - Automobile Driver Depresses the Accelerator Pedal
  - Systems: The automobile
  - Input Signals: The pressure on the acceleration pedal.
  - Output Signals: Automobile speed

0.3 Historical Perspective

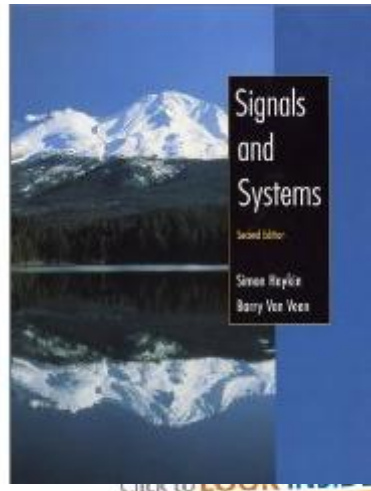
- 17th Century
  - Invention of the Calculus (Newton, 1642-1727)
  - Model physical phenomena in terms of functions of continuous variables and differential equations.
- 18th Century
  - Euler (1707-1783)
  - Bernoulli (1700 - 1782)
  - Lagrange (1736-1813)
- 19th Century
  - Gauss (1777 - 1855)
  - Fourier (1772- 1837)

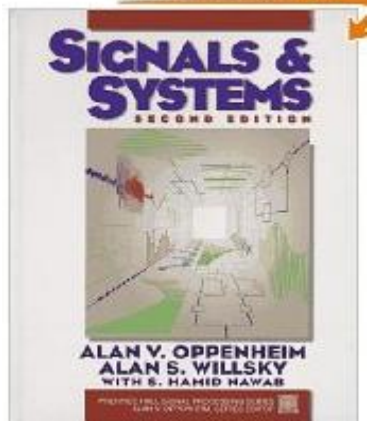
0.3 Historical Perspective (c.1)

- Digital Computer (1950s)
  - Analog Systems were used for real-time applications
  - The need for sophisticated signal processing
    - Oil prospecting.
  - Digital computers are used to simulate & approximate analog systems.
- Microelectronics
  - Wafer-scale integration
- DSP Processors
  - Flexibility and High Computing Speeds
  - High speed fixed point and floating point processor.
- Personal Computers
  - Storage
  - Computing Power
  - Media Applications

0.4 Contents-- Topics & Textbooks

- Discussed Topics
  - The concepts of signals and systems arise in an extremely wide variety of fields.
  - Although the physical nature of the signals and systems may be drastically different, there are common tools for signal analysis and system design.
  - These common tools are the discussed topics in this course.
- Objective of the Course
  - Provide the reader with the knowledge necessary for the wide scope of applications for signals sand systems
- Text Books
  - Simon Haykin and Barry Van Veen, "Signals and Systems," Wiley 2003, 2nd edition
- Reference Books
  - A.V. Oppenheim and A.S. Willsky, " Signals and Systems," Prentice Hall, 1987.





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0.4 Contents-- Outline & Time Scheduling

- Preface
- Signals and Systems
- Time-Domain Representations of Linear Time-Invariant Systems
- Fourier Representations of Linear Time-Invariant Systems
- Application of Fourier Representations to Mixed Signal Classes
- The Laplace Transform
- The z-Transform
- Application to Filters and Equalizers

0.5 Related Courses in NCTU

Course Links in Our Departments

- Mathematics
  - Differential Equations
  - Linear Algebra
- CS Courses
  - Electronics & Electrical Circuits
  - Computer Programming and Peripherals
- Advanced Courses & Applications
  - Image Processing
  - Audio Processing
  - Speech Processing
  - Neural Network
  - Communication
  - …

0.6 Requirements

- Presentation (2h/week)
  - Slides
- Discussion (1h/week)
  - Homework and Matlab
  - Tests
  - Reviewing
- Prospects
  - Be able to tackle about the assigned homework.
  - Have a reading time at least 3 hours per week.
- Homeworks
  - Problems
- Score Decision
  - Homeworks & Matlab& Test (40%)
  - 3 Examinations (60%)