Physical Signals

1. **Course number and name:** 020SPHCI1 Physical Signals

2. **Credits and contact hours:** 6 ECTS credits, 3x1:15 contact hours

3. **Name(s) of instructor(s) or course coordinator(s):** Remi Z. DAOU

4. **Instruction materials:**
   Textbook : Physique MPSI/MP2I – Tout-en-un, J'intègre – DUNOD (2ème édition)

5. **Specific course information**
   a. **Catalog description:**
   The course is concerned with a wide range of concepts already introduced at high school: periodic signals, spectrums, electrical energy, Ohm's law, Joule's law, lenses, wave length, light spectrum, numerical signal, travelling wave, diffraction, interferences, Doppler effect, Newton's law, mechanical energy, harmonic oscillator. It assures a smooth transition toward a more quantitative physics than the one seen at high school.

   b. **Prerequisites:** None

   c. **Required/Selected Elective/Open Elective**: Required

6. **Specific goals for the course**
   a. **Specific outcomes of instruction:**
      - Characterize a light source by its spectrum. Link wavelength in a vacuum to color.
      - Define the geometrical optics model. Indicate the limits of the geometrical optics model.
      - Establish the condition of total reflection.
      - Construct the image of an object in a plane mirror.
      - State the conditions of the Gaussian approximation and its consequences.
      - Relate approximate stigmatism to the characteristics of a detector.
      - Define the properties of the optical center, principal and secondary foci, focal length and vergence.
      - Construct the image of an object at a finite or infinite distance using light rays and identify whether it is real or virtual.
      - Use Descartes' and Newton's formulae for conjugation and transverse magnification.
      - Establish and use the condition for the formation of the real image of a real object by a converging lens.
      - Model the eye as a combination of a variable vergence lens and a fixed plane sensor.

- Quote the orders of magnitude of the angular resolution limit and the accommodation range.
- Model the camera as a combination of a lens and a sensor.
- Geometrically construct the depth of field for a given setting.
- Establish the expressions for the acceptance cone and intermodal dispersion of a step index fiber.
- Justify that the use of continuous electrical quantities is compatible with the quantification of electrical charge.
- Express the intensity of the electric current in terms of charge flow.
- Express the ARQS application condition as a function of circuit size and frequency.
- Relate the law of nodes to the postulate of conservation of charge.
- Use the law of meshes.
- Algebraize electrical quantities and use the receiver and generator conventions.
- Quote the orders of magnitude of currents and voltages in different fields of application.
- Use the relationships between current and voltage. Quote the orders of magnitude of the components R, L, C.
- Express the power dissipated by the Joule effect in a resistor.
- Express the energy stored in a capacitor or coil.
- Model a source using Thevenin's representation.
- Replace a series or parallel combination of two resistors by an equivalent resistor.
- Establish and use the voltage or current divider relationships.
- Distinguish, on an experimental record, between transient and steady state conditions during the evolution of a first-order system subjected to a voltage step.
- Interpret and use the continuity of the voltage across a capacitor or the current through a coil.
- Establish the first-order differential equation verified by an electrical quantity in a circuit with one or two meshes. Determine the time response in the case of a free-running circuit or a voltage step. Determine the order of magnitude of the transient duration.
- Draw up an energy balance.
- Establish and recognize the differential equation that characterizes a harmonic oscillator; solve it given the initial conditions.
- Characterize the movement using the concepts of amplitude, phase, period, frequency and pulsation.
- Draw up an energy balance.

- Use experimental data to analyses changes in the shape of transient regimes as a function of characteristic parameters.
- Predict the evolution of the system on the basis of energy considerations.
- Write the differential equation in canonical form in order to identify the natural pulsation and the quality factor.
- Describe the nature of the response as a function of the value of the quality factor.
- Determine the detailed response in the case of a free-running system or a system subjected to a step by finding the roots of the characteristic polynomial. Determine an order of magnitude for the duration of the transient regime according to the value of the quality factor.
- Carry out an energy balance.
- Establish and know the impedance of a resistor, capacitor or coil.
- Replace a series or parallel combination of two impedances by an equivalent impedance.
- Use the complex representation to study the forced regime.
- Relate the acuity of a resonance to the quality factor. Determine the natural frequency and the quality factor from experimental amplitude and phase graphs.
- Draw the Bode diagram (amplitude and phase) associated with a transfer function of order 1.
- Use a given transfer function of order 1 or 2 (or its graphical representations) to study the response of a linear system to a sinusoidal excitation, to a finite sum of sinusoidal excitations or to a periodic signal.
- Use logarithmic scales and interpret the straight lines in the amplitude Bode diagrams from the expression of the transfer function.
- Explain the conditions for using a filter as an integrator or derivator.
- Identify the physical quantities corresponding to acoustic, electrical and electromagnetic signals.
- Write signals in the form $f(x-ct)$ or $g(x+ct)$. Write signals in the form $f(t-x/c)$ or $g(t+x/c)$. Predict, in the case of a travelling wave, the time evolution at a fixed position and the spatial evolution at different times.
- Quote a few orders of magnitude for frequencies in the acoustic, mechanical and electromagnetic fields.
- Establish the relationship between frequency, wavelength and phase velocity.
- Relate the phase shift between signals perceived at two different points to the propagation delay.
- Define a dispersive medium.
- Give examples of dispersive and non-dispersive propagation.
- Express the conditions for constructive or destructive interference.

- Determine the amplitude of the resulting wave at a point as a function of the phase shift.
- Relate the phase shift between the two waves to the optical path difference.
- Establish the literal expression for the optical path difference between the two waves.
- Use the Fresnel formula to describe the light intensity distribution.

b. PIs addressed by the course:

PI	1.3	7.1
Covered	x	x
Assessed	x	

7. Brief list of topics to be covered

- Monochromatic point source model - Spectrum - Geometrical optics model - Concept of light ray - Index of a transparent medium - Reflection - Refraction - Snell-Descartes laws (1 lecture)
- TD (2 lectures)
- Conditions of the Gaussian approximation and applications - Stigmatism - Plane mirror - Thin lenses in the Gaussian approximation (2 lectures)
- TD (2 lectures)
- Models of some optical devices - The eye - The camera - Optical fibre with index jump (2 lectures)
- TD (3 lectures)
- Electric charge - Intensity - Potential reference - Voltage - Power - Dipoles: resistors, capacitors, bibine, sources described by a linear model - Association of two resistors - Output resistance - Input resistance (2 lectures)
- TD (3 lectures)
- Free regime - Response to a voltage step - Energy storage and dissipation (1 lecture)
- TD (2 lecture)
- Harmonic oscillator - Example of the LC circuit and the mechanical oscillator (1 lecture)
- TD (1 lecture)
- Series RLC circuit and mechanical oscillator damped by viscous friction (2 lectures)
- TD (2 lectures)
- Complex impedance - Association of two impedances - Electrical or mechanical oscillator subjected to sinusoidal excitation - Resonance (2 lectures)
- TD (3 lectures)
- Harmonic transfer function - Bode diagram - Passive filter models: low-pass and high-pass of order 1, low-pass and band-pass of order 2 (2 lecture)
- TD (2 lectures)
- Examples of signals - Sinusoidal signal - Propagation of a signal in an unlimited, non-dispersive and transparent medium - Travelling wave in the case of one-dimensional non-dispersive propagation - Velocity, time delay - Model of the one-dimensional

sinusoidal travelling wave - Phase speed - Phase shift - Double spatial and temporal periodicity - Dispersive or non-dispersive media (3 lectures)

- TD (3 lectures)
- Interference phenomena - Interference between two acoustic or mechanical waves of the same frequency - Interference between two light waves of the same frequency. Example of Young's holes device illuminated by a monochromatic source - Optical path difference. Conditions for constructive or destructive interference - Fresnel's formula (2 lectures)
- TD (3 lectures)