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:** Slides, Handouts
   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. **Educational objectives for the course**
   a. **Specific outcomes of instruction:**
      - Characterize a light source by its spectrum. 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. 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. 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.
      - Algebraize electrical quantities and use the receiver and generator conventions. Use the relationships between current and voltage. 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. Establish and use the voltage or current divider relationships. 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. Establish and recognize the differential equation that characterizes a harmonic oscillator; solve it given the initial conditions. Write the differential equation in canonical form in order to identify the natural pulsation and the quality factor. Establish and know the impedance of a resistor, capacitor or coil. Use the complex representation to study the forced regime. Draw the Bode diagram associated with a transfer function of order 1.

- Identify the physical quantities corresponding to acoustic, electrical and electromagnetic signals. Predict, in the case of a travelling wave, the time evolution at a fixed position and the spatial evolution at different times. 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. 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.

b. PIs addressed by the course:

PI	1.2	1.3
Covered	x	x
Assessed	x	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). Tutorials (2 lectures)
- Conditions of the Gaussian approximation and applications - Stigmatism - Plane mirror - Thin lenses in the Gaussian approximation (2 lectures). Tutorials (2 lectures)
- Models of some optical devices - The eye - The camera - Optical fibre with index jump (2 lectures). Tutorials (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). Tutorials (3 lectures)
- Free regime - Response to a voltage step - Energy storage and dissipation (1 lecture). Tutorials (2 lecture)
- Harmonic oscillator - Example of the LC circuit and the mechanical oscillator (1 lecture). Tutorials (1 lecture)
- Series RLC circuit and mechanical oscillator damped by viscous friction (2 lectures). Tutorials (2 lectures)
- Complex impedance - Association of two impedances - Electrical or mechanical oscillator subjected to sinusoidal excitation - Resonance (2 lectures). Tutorials (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). Tutorials (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). Tutorials (3 lectures)
- Interference phenomena - Example of Young's holes device illuminated by a monochromatic source - Optical path difference. (2 lectures). Tutorials (3 lectures)