SIMULATING PHYSICAL PHENOMENA WITH MICROSOFT EXCEL

BY

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Abstract. The study presents a way to simulate certain physical phenomena, such as the composition of linearly harmonic oscillations or the polarization state of radiation, within Microsoft Excel. Those simulations aid the students to familiarize themselves with the graphical representation of the movement laws of a linear harmonic oscillator. Additionally, they can help in the study of special cases of coupling two linearly harmonic, either parallel or perpendicular, oscillations and in the understanding of ways to obtain different states of light polarization through the composition of several, conveniently out of phase, linearly polarized radiations.

Keywords: composition; oscillation; harmonic; light; polarization.

1. Introduction

"The Composition of Linearly Harmonic Oscillations" application window uses input data:
- Oscillations amplitude (A_1, A_2 in mm);
- Initial phases of the oscillations (in degrees);
- Oscillations period or pulse.

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Output data:

• Graphical representation of the oscillations $y_1(t)$, $y_2(t)$ and y_{rez} (equation of the resulting oscillation);

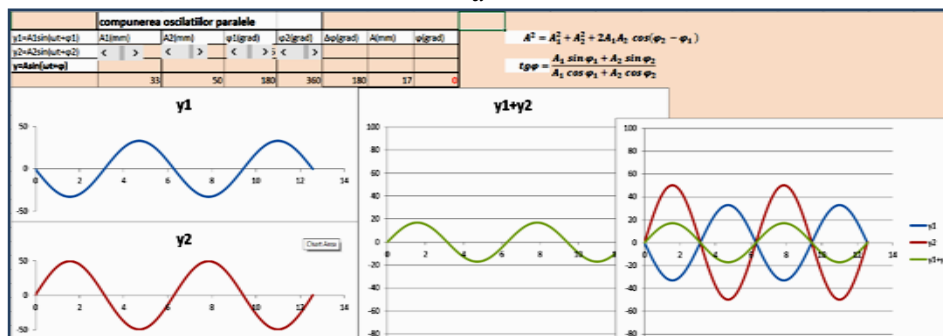• Amplitude, oscillations phase offset, initial phase of the resulting oscillation.

2. Composition of Two Linearly Harmonic, Parallel Oscillations with Equal Frequencies

The application window allows for the study of composing two linearly harmonic, parallel oscillations with equal frequencies (Popescu *et al.*, 2006), for highlighting the special cases involving in-phase oscillations (Fig. 1*a*) with maximal value for the resulting amplitude, antiphase oscillations (Fig. 1*b*), with minimal value for the resulting amplitude, and the case of quadrature oscillations.

One can independently modify the values for oscillation amplitude and initial phase. Expressing the initial phase in degrees was preferred in order to be more suggestive for students and because was chosen a value of 1 degree for each incremental variation of the initial phase.
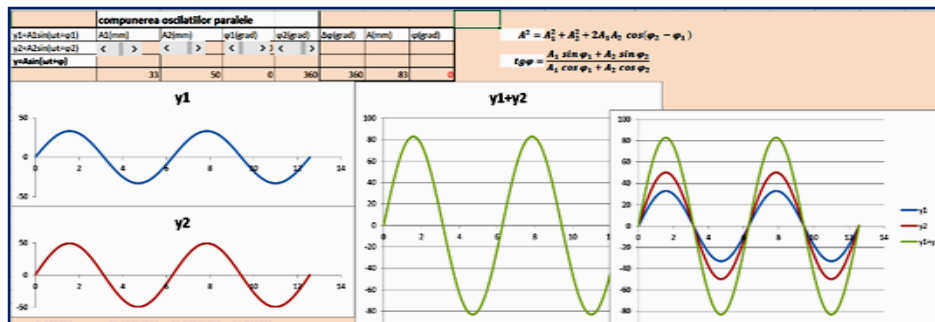
a

b

Fig. 1 – *a*) Combining two linearly harmonic, in-phase, parallel oscillations with equal frequencies, *b*) Combining two linearly harmonic, parallel, antiphase oscillations with equal frequencies.

3. Composition of Two Harmonic Oscillations of Different Frequencies Highlighting the Beat Phenomenon

Two linearly harmonic oscillations with the same amplitude and initial phase were graphically represented (Fig. 2). The periods and, consequently, the pulse of the oscillations can be modified. In the case of oscillations with the same pulse, we encounter the previous situation.

The students can now understand that the amplitude of the resulting oscillation is variable. The period increases with the decreasing of the difference between the pulse of the components. The resulting oscillation has a pulse equal to the mean of the two pulse values and a period much smaller than the one characterizing the variation in amplitude. One can now observe how the difference between the two pulse values can influence the aspect of the resulting oscillation.
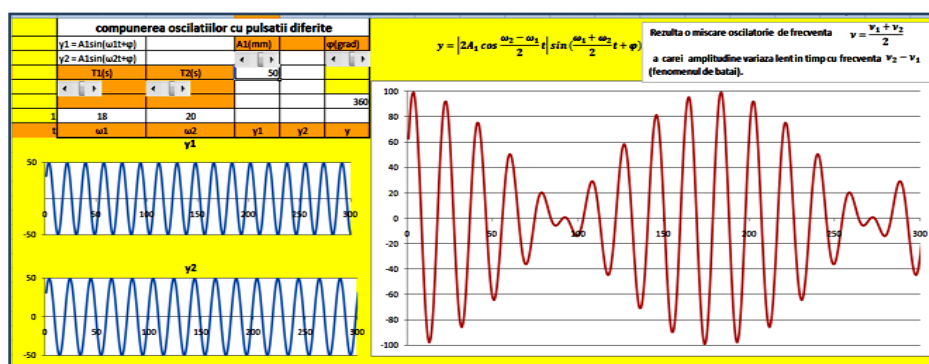

Fig. 2 – Combining two oscillations with different yet close pulse
values – Highlighting the beat phenomenon.

4. Superposition of Perpendicular Harmonic Oscillations (the Lissajous Figures)

In this section two perpendicular oscillations, with modifiable amplitude and initial phase, were combined (Fig. 3). Additionally, the pulse values for these oscillations are not equal, being characterized by a proportionality relationship "*n*", where "*n*" can be either integral or fractional. The curves resulting from this situation are called the Lissajous figures. In Fig. 3, the trajectories corresponding to a few values for the proportionality relationship "*n*" were represented ($n = 1$, $n = 2$, $n = 6$).
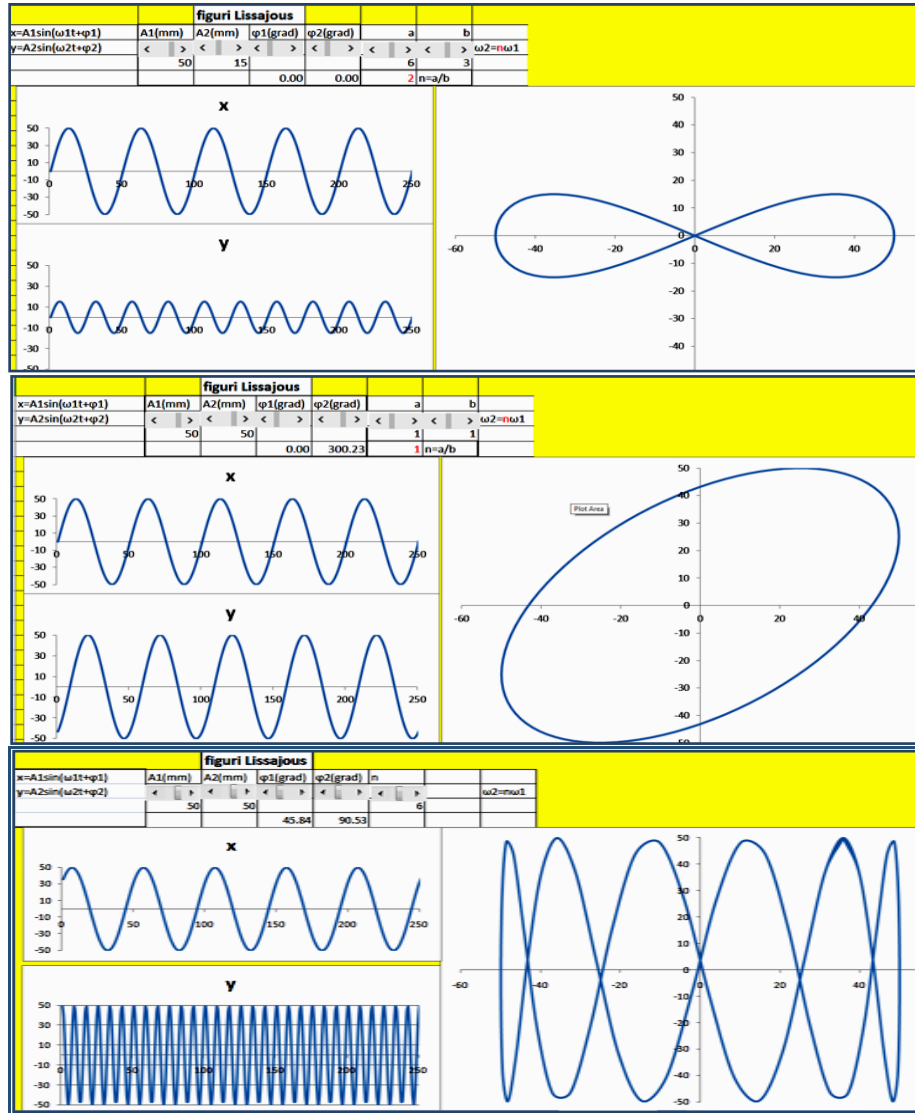
Fig. 3 – Combining two perpendicular oscillations (the Lissajous curves).

5. Application Description "Modelling the State
of Polarization of Light"

The previous application allows for the modelling of the states of polarization of light, seenas a result of the composition of two perpendicular oscillations with equal pulse.

This approach is justified when the polarization of the light obtained through birefringence (Bruhat, 1965; Kužel, 2000/2001) consisting in the production of two refracted rays for each incident ray on an anisotropic crystal.

The two rays are polarized in perpendicular planes: in the ordinary ray, the oscillations of the electric field intensity occur perpendicularly to the main plane, while in the case of the extraordinary ray, the oscillations occur in a plane parallel to the main section one, as determined by the incident ray and the direction of the optic axis.

Should the propagation direction of the two rays be the optic axis, the two will have identical speed values, otherwise, the speeds differ. Due to the different speeds of propagation, a phase offset occurs between the two rays causing a change in the state of polarization for the radiation passing through a layer of anisotropic substance.

We will consider that the elliptical polarization corresponds to the general state of total polarized light. Depending on the values of the phase offset δ, the states of polarization for totally polarized radiations can be obtained as special cases of elliptical polarization (Table1).

Table 1

Polarization States of Electromagnetic Radiations in
Relation with the Phase Offset Value

Nr.crt.	Phase offset value	State of polarization
1.	$\delta = \delta_y - \delta_x = m\pi$, $m = 0, 1, \ldots$	Linear
2.	$\delta = \delta_y - \delta_x = \pm \pi/2$ $E_{0y} = E_{0x}$	Circular
3.	$\delta \in (0, \pi)$	Right elliptical
	$\delta \in (\pi, \ 2\pi)$	Left elliptical
	$\delta = \pm \pi / 2$	Elliptical the axes of the ellipse coincide with the Ox and Oy axes.

The states of polarization can be represented with the help of the Stokes parameters (Guenther, 1990). In the ideal case of a plane, fully polarized, monochromatic wave, the matrix of the normalized Stokes parameters can be expressed in relation to ψ (tg $\psi = E_{0x}/E_{0y}$, where E_{0x} and E_{0y} are the electric field intensity amplitudes for the two perpendicular oscillations) and δ according to Eq. (1).

$$\begin{pmatrix} s_0 \\ s_1 \\ s_2 \\ s_3 \end{pmatrix} = \begin{pmatrix} 1 \\ -\cos 2\psi \\ \sin 2\psi \cos \delta \\ \sin 2\psi \sin \delta \end{pmatrix} \tag{1}$$

For a linearly polarized, incident radiation that propagates perpendicularly to the optic axis of an anisotropic uniaxial medium, an Excel application was developed to allow for the modification of the phase offset between the ordinary and the extraordinary rays and also, to obtain the different states of polarization for the emerging radiation.

In order to modify the phase, offset values of the two oscillations an increment/decrement button type form controller was added. In the application window the electric field intensity oscillations on the two perpendicular axes Ox and Oy (the directions of the neutral lines of the anisotropic medium) and the shape of the oscillation resulting from the combination of the two, were illustrated (Figs. 5-7).

The application also allows for the determination of the Stokes vectors for each state of polarization. The vector elements can be placed with the desired precision.
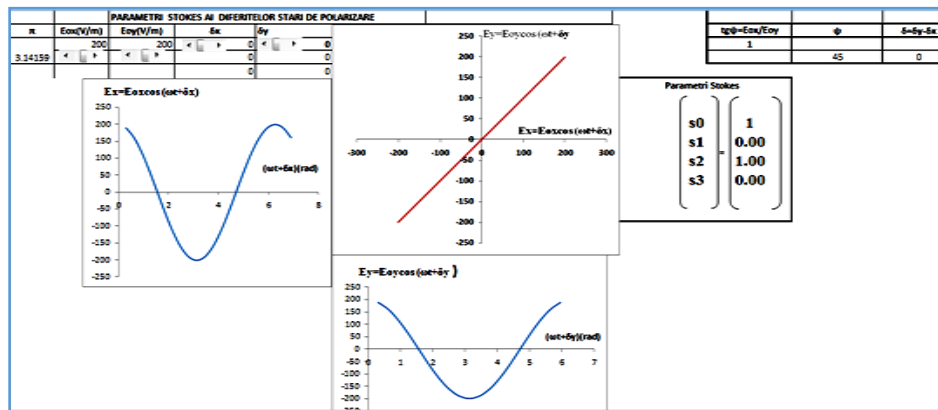

Fig. 4 – Linearly polarized radiation orientated at a 45° angle
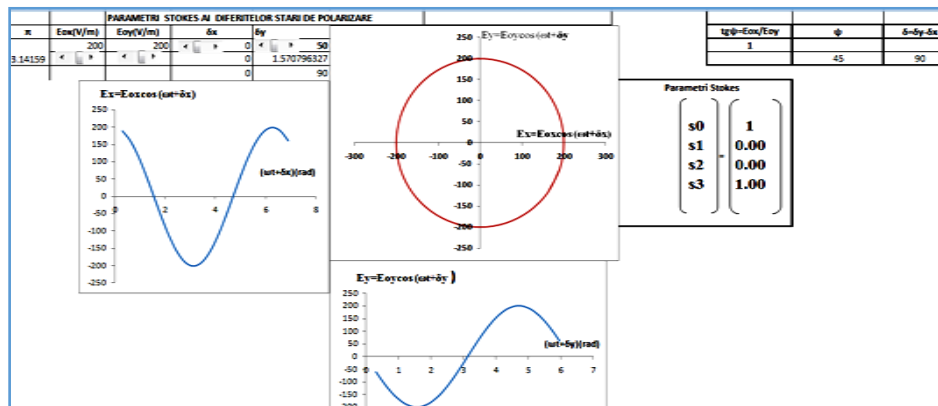in relation with the XOY coordinate system.

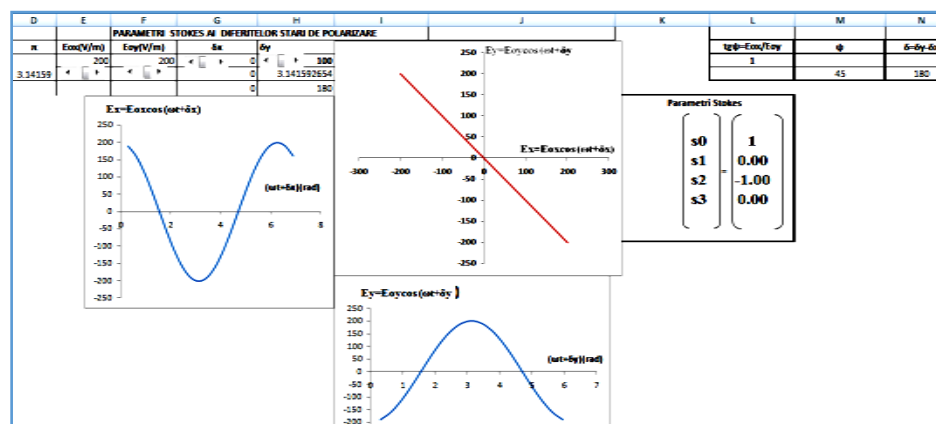Fig. 5 – Circularly polarized right radiation.

Fig. 6 – Linearly polarized radiation with modified azimuth.

6. Conclusions

Simulating and modelling physics phenomena, that are difficult to recreate in the school laboratory, with the help of computer software helps the students to better understand and broaden their knowledge of the phenomena while transforming the computer into a virtual lab.

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SIMULAREA UNOR FENOMENE FIZICE CU AJUTORUL APLICAŢIEI MICROSOFT EXCEL

(Rezumat)

Studiul prezintă modul în care pot fi simulate unele fenomene fizice, precum compunerea oscilaţiilor liniar armonice sau starea de polarizare a radiaţiilor, în aplicaţia Microsoft Excel. Simulările îi ajută pe elevi: să se familiarizeze cu interpretarea grafică a legilor de mişcare pentru un oscillator liniar armonic, să studieze cazuri de interes pentru compunerea a două oscilaţii liniar armonice paralele sau perpendicular şi să înţeleagă cum se pot obţine diferite stări de polarizare a luminii prin compunerea unor radiaţii liniar polarizate defazate convenabil.