An online laboratory in Optical Instrumentation: The Compound Microscope

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Abstract *— OpenLab is a project created to provide an online environment that complements the traditional classroom and laboratory methods. The here-presented work is focused on an online Physics laboratory. Specifically, this is a self-learning material concerned with Optical Instrumentation and, as a first step, we have prepared an online-simulation content on the principles of the compound microscope. First, this framework provides an online test in order to establish the compound microscope arrangement as a combination of a objective lens and an ocular lens (simple eyepiece). Several simulations make use of simple parameters controlling the behavior of the compound microscope. Image focal lengths of the objective and the ocular lenses and the optical tube length may be modified in order to control the objective lateral magnification, position of the exit pupil and the field of view. Also the object-position tolerance in the optical system is handled. Multimedia simulations reproduce a direct observation and online tests check the geometrical characteristics of the compound microscope. Additionally, by using the intermediate image we apply the reticule basis. Some examples are employed to measure an object lateral size. Finally, the tutorial system allows determining the normal magnification of the compound microscope having a doublet as an eyepiece. In resume, this innovative web-based teaching strategy allows a 24 hours access to the laboratory, profiting from training without the presence of teachers.*

Index Terms *— Autonomous learning, online laboratory, optical instrumentation.*

INTRODUCTION

Recently, Information and Communication Technologies (ICTs) are widely used in Education Science. Traditional pedagogical methodologies are centered on the subject and professor labor, which are being substituted by educational processes centered on the student. According to the constructivism principles, ICTs benefit from a permanent interactivity [1]. In particular, educative processes based on digital simulations have shown additional advantages [2]-[4]. However, it should be emphasized that pedagogical effectiveness strongly requires a complete integration of these simulations into a global instructional plan [5],[6].

OpenLab is a project created to provide an online environment that complements the traditional classroom and laboratory methods. Permanent access to educational material related to physical and engineering experiments involves a relevant advantage on the comprehensive process for the student. Digital simulations and real-time videos that benefit from virtual reality should substitute observable phenomena. The here-presented work is an innovative material for autonomous learning based on some laboratory experiences on optical instrumentation and optometry [7].

As a first step we have prepared a virtual tool focused on the principles of the compound microscope. This is a web-based material that allows the student to reproduce the experiences performed in the laboratory. Also this may be used as an introductory material previous to a real application of the optical instrument. Additional online self-tutorial tests complement the pedagogical process.

SIMULATIONS AND VIRTUAL EXPERIENCES

This online laboratory is programmed in standard HTML in order to be explored by Netscape, Internet Explorer and similar internet software. Server privileges are removed in order to meet the students' home Internet facilities. The here-presented work is a part of OpenLab, which is a project created to provide an online environment that complements the traditional classroom and laboratory methods. Several virtual experiences inspired in laboratory experiments are integrated in an online environment controlled by WebCT software. Since the interest of this paper is focused on a particular virtual experience related on the composed microscope, we give extensive details of the structure and possibilities of the developed web page.

This is structured in four main parts: a) a theoretical introduction, b) the interactive virtual experiences, c) online tests, and d) links to related sites with microscopy digital simulations.

After an extensive theoretical introduction on the basis of microscopy, this interactive environment first presents a window where some parameters are introduced. The values of the geometrical parameters characterize the compound microscope arrangement, comprised by an objective lens and a simple eyepiece (ocular lens). The front focal lengths, f_o and f_e, and the diameters, ϕ_o and ϕ_e, of both the objective lens and the eyepiece may be modified amongst several selected values, as well as the tube length, t, that takes into account the distance between both optical elements. The basic optical properties of the image-forming instrument may be controlled, i.e., the lateral magnification of the objective lens, β_o, the visual magnification of the compound microscope, Γ, and the field of view, ρ_m, as seen in (1)-(3). Also the position of the exit pupil may be modified, given in terms of the exit emergence, a_p, in (4), what determines the position of the observer ocular pupil.

Next we present some multimedia visualizations making use of the previously defined parameters. A schematic figure shows the position of the elements of the compound microscope (see Figure 1). The student watch on an adjacent window an image as a result of selecting the geometrical parameters previously introduced in the online application. Observable differences in between the offered possibilities are, on one hand, easily detectable and, on the other hand, they can be reproduced in the corresponding laboratory experience it is based on.

Also, these digital simulations are complemented with online tests. They allow the student to check the values of the optical and geometrical characteristics of the compound microscope. Additional questions are presented in order to prove the perfect understanding of simple concepts concerning image formation, visual magnification and field-of-view limiting. These tests are reproducible, as many times the student needs to ensure the correct answer. Permanent help is included since the student has the possibility to send an email to a professor that coordinates this virtual experience.

Finally, this tutorial system offers additional digital simulations and auto-checked tests adapted to a microscope composed by a composed eyepiece and a reticule used for the direct measurement of a real size of an object (see Figure 2). In the first case, it is possible to compare the microscope optical behavior when an ocular simple lens is used and when a field lens is included. In these simulations it is possible to modify the focal length of the field lens, f_F, in order to modify as desired the visual field of the instrument. Visual field increases as a direct consequence of reducing the exit emergence of the optical instrument shown in (5). The use of a reticule has a special interest since we have access to an intermediate image generated by the objective lens as seen in Figure 3. Some theoretical and practical questions are included for the student to check the comprehensive level of the acquired concepts.

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FIGURES, TABLES AND EQUATIONS

$$\beta_o = -t/f_o \,. \qquad (1)$$

$$\Gamma = \beta_o \Gamma_e \,, \text{ where } \Gamma_e = 250\, mm/f_e \,. \qquad (2)$$

$$\rho_m = (f_o / 2t)\, [\phi_e (f_o + t)/(f_o + t + f_e)] \,. \qquad (3)$$

$$a_p = f_e + f_e^2/(f_o + t)\ . \qquad (4)$$
$$a'_p = a_p - f_e^2/f_F\ . \qquad (5)$$

FIGURE 1
THE COMPOUND MICROSCOPE IS AN OPTICAL ARRANGEMENT WHERE AN OBJECTIVE LENS IS LOCATED AT A DISTANCE $f_o + t + f_e$ FROM AN OCULAR LENS.

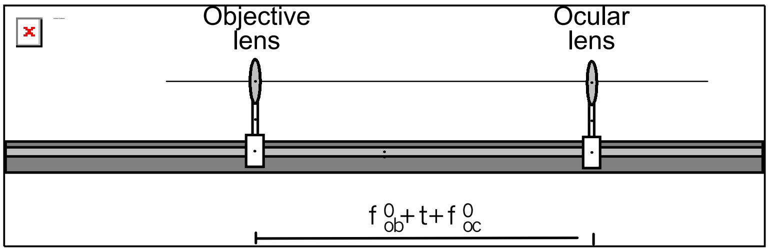

FIGURE 2
IN THIS EXAMPLE, THE INTERMEDIATE IMAGE IS FIVE FOLD HIGHER THAN THE RETICULE SCALE. NOTE THAT A NON-INVERTED IMAGE REQUIRES AN INVERTED OBJECT.

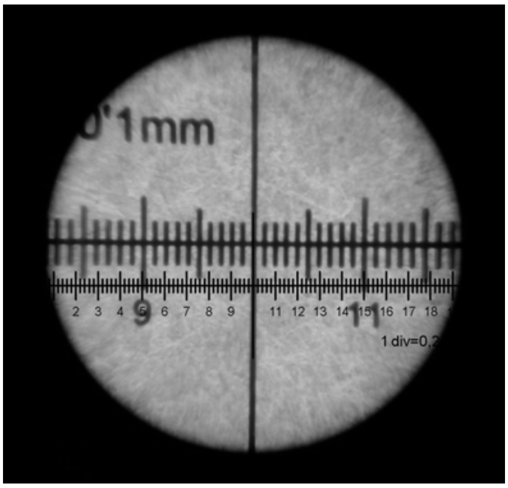

FIGURE 3
PICTURE OF A LABORATORY OPTICAL ARRANGEMENT USED FOR THE MEASUREMENT OF THE OBJECTIVE LATERAL MAGNIFICATION. THIS ARRANGEMENT MAY BE EMPLOYED TO DETERMINE THE FIELD OF VIEW.