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Implementation of a platform for the remote access to a transmission Mössbauer spectrometer

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Abstract
In this work, we present the development of a platform for the remote access to the Mössbauer spectrometer of the Instrumentation and Spectroscopy Laboratory of Universidad EAFIT of Medellín, Colombia. This platform was developed looking for a proper use of the radioactive source of ^{57}Co(Rh) during recess periods of the staff of the laboratory, reduction of exposure of the users to the ionizing radiation coming from radioactive source, as well as spread Mössbauer spectroscopy between new researchers during their academic formation in materials characterization. The application is executed from the server "Neutrón" of the "Laboratorio para la Innovación y el Aprendizaje" of Universidad EAFIT of Medellín. Through a web application based on the e-learning platform Moodle, the user can access, after registration, to a web site with a series of introductory contents related to Mössbauer spectroscopy, a field with remote connection to the Mössbauer spectrometer and other fields with support materials, among them: suggested papers, video of the experiment through an IP camera, chat with the administrator of the spectrometer and access to the file with the experimental spectra. Details of the design of the platform are presented through the sections of this paper.

Keywords Mössbauer spectrometer · Remote access · Moodle · e-learning

1 Introduction

Internet is a good tool to share laboratory infrastructure when the measuring equipment is programmable, because measurements can be automated, monitored remotely and shared

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by multiple users. Nowadays, is possible to take advantage of information and communication technologies, among them e-learning tools, programmable measuring instruments with ports RS-232, Ethernet, USB, IEEE-488, web cameras, chat, voice, storage of information in the cloud, among others. These tools have been implemented in educative environments in order to increase the scope of traditional tools of learning and teaching [1, 2], commonly based on classroom assisted activities. In the field of physics laboratories several remote platforms have been implemented. Only to mention some cases, is convenient highlight remote platforms such as RCL: Remotely Controlled Laboratories [3], which implements an integral methodology for the learning of concepts in modern physics and mechanics, with both theoretical and experimental focuses; the remote platform ELAB-FSBM developed by Khazri and coworkers [4] for experimentation in electronic circuits and acoustics, by using facilities of LabVIEW software; the remote platform implemented by Arroyave and coworkers [5] and Montoya and coworkers [6] for the control of laboratory equipment, such as a scanning probe microscope, a programmable oscilloscope, an arbitrary waveform generator and a current source; the "Red de Laboratorios Virtuales y Teleoperados de Colombia" [7], where some experiments in robotics, virtual courses and access to cameras can be performed.

In the field of Mössbauer spectroscopy, a few cases of remote control of the spectrometer have been reported by Silaev and coworkers [8], Zhou and coworkers [9] and Klingelhöfer and coworkers [10], being this last implementation developed for the mini spectrometer MIMOS II for Mars exploration. Remote platforms for the control of Mössbauer spectrometers assisted by learning objects seem to be a topic little explored, being this methodology a good option to allow cooperative work between researchers of different laboratories, bring young researchers closer to the Mössbauer technique, take advantage of the useful life of the radioactive source of the spectrometer, offer online courses and services of Mössbauer spectroscopy, among other benefits. The previous background motivated us to develop a platform for the remote access to the Mössbauer spectrometer of the Instrumentation and Spectroscopy Laboratory of EAFIT University of Medellín, Colombia, whose implementation is described in the following sections.

2 Remote platform

2.1 Access to the platform

The user can access to the platform through the web site [11]. The banner of the web site is presented in Fig. 1, where a username and a password are asked for access to the platform.

After obtaining a valid username and password, the user can access to the platform presented in Fig. 2, where some remote experiments of basic and advanced physics have been implemented, among them the Mössbauer spectrometer is pointed. This platform was developed with the tool *Modular Object Oriented Dynamic Learning Environment* (Moodle), version 3.5, which is free software for the management of learning objects, widely used in educational environments because of its intuitive and flexible nature [12].

2.2 Fields of the platform

When the user accesses the application 5, labeled "Espectrómetro Mössbauer", he finds the sections presented in Fig. 3. These sections address four fields, namely: 1. Introductory section, 2. Remote access to the Mössbauer spectrometer, 3. Access to experimental

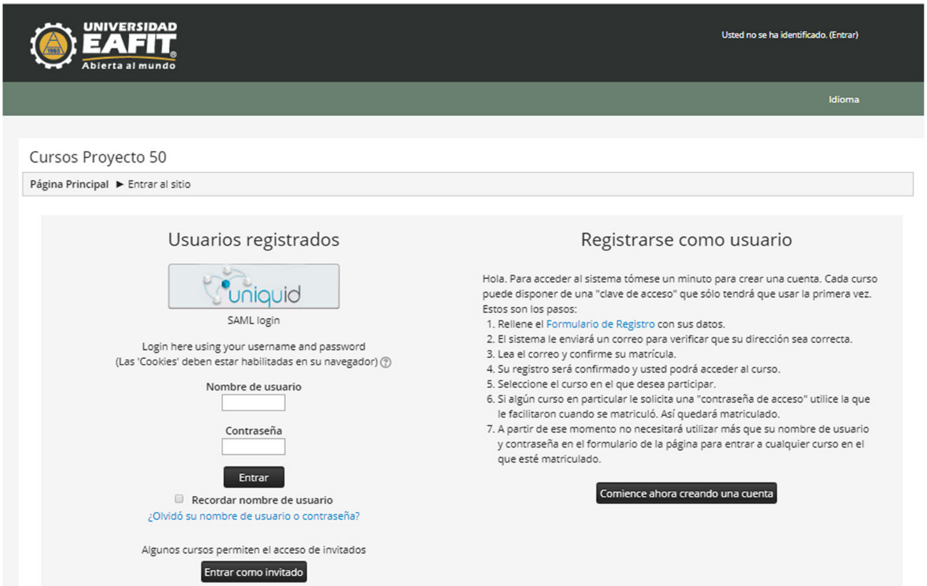


Fig. 1 Web site for remote access to the Mössbauer spectrometer of EAFIT University

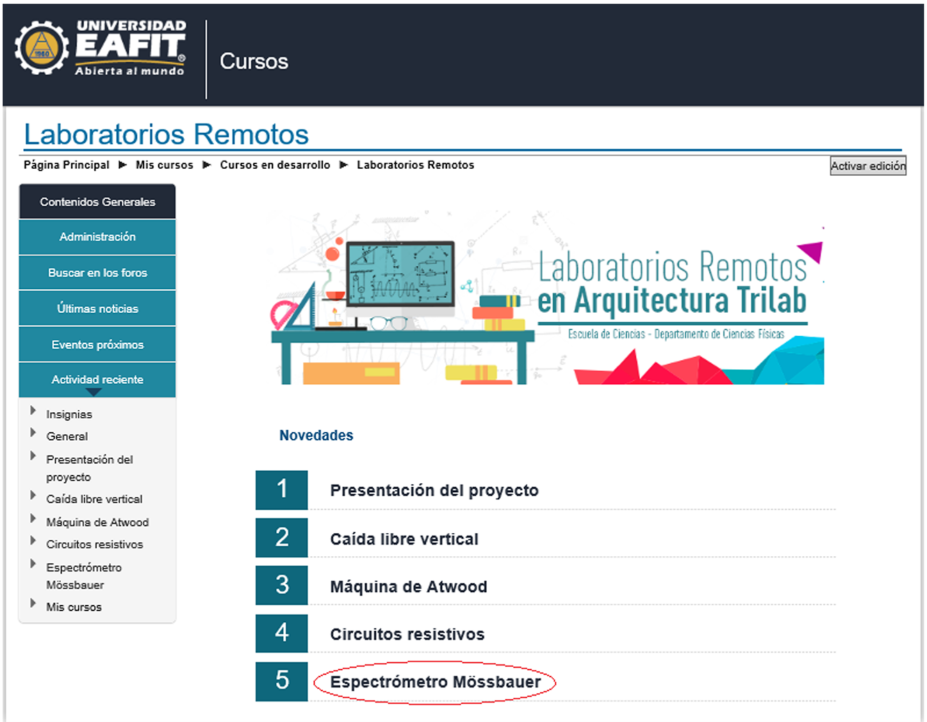


Fig. 2 Moodle platform for remote access to the Mössbauer spectrometer of EAFIT University

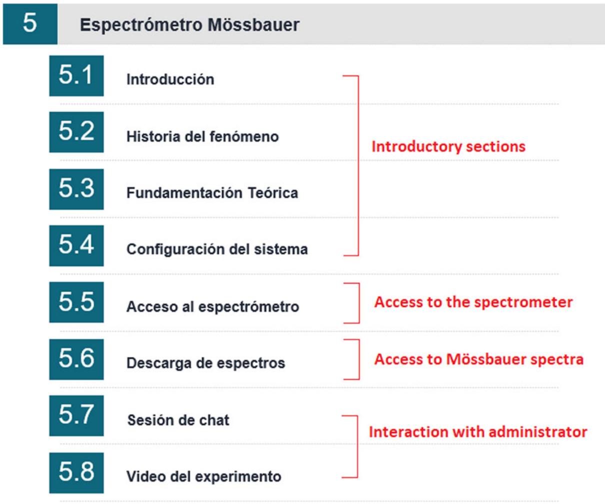


Fig. 3 Sections of Mössbauer remote platform

Mössbauer spectra and 4. Interaction with the platform administrator. Initially all information of the platform is written in Spanish because it has been implemented with all courses offered in Spanish. A subsequent version will be developed in English language when the platform has been widely tested and approved in an English version by the Communication Department of EAFIT University. The fields of platform are described in the following sections.

2.2.1 Introductory field

This field covers the Sections 5.1–5.4, which address some historical aspects of Mössbauer spectroscopy, such as the Mössbauer effect discovery and some applications of Mössbauer spectroscopy to the study of materials. Some bibliographic references [13–17] are suggested to the user in order to reinforce his knowledge about generalities of the Mössbauer effect. This section also contains the theoretical bases of the Mössbauer effect as well as the hyperfine interactions and their physical meaning. Details of the architecture of a Mössbauer spectrometer in the modes of transmission (TMS) and internal conversion electrons (CEMS) are presented in Section 5.4. Some views of the introductory sections of the remote platform are presented in Figs. 4, 5 and 6.

2.2.2 Remote access to the Mössbauer spectrometer

Section 5.5, labeled “Acceso al espectrómetro” in Fig. 3 allows the user access to the remote platform. After access the user observes a graphic interface developed in LabVIEW software, whose fields are presented in Fig. 7. For executing this application, the user must install the free application LabVIEW Runtime Engine, which can be downloaded from the web site [18].

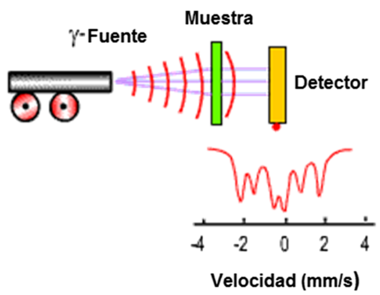
By making right click on any place of the graphic interface, the user observes a dialog box with the option labeled “Request control of Virtual Instrument (VI)”, after select this option, all fields of the application are enabled and the user has access to the user menu


Fundamentación Teórica

La espectroscopía Mössbauer también se conoce como emisión y absorción resonante de rayos gamma sin pérdida de energía por retroceso. El retroceso mecánico hace referencia a que un núcleo libre, durante la emisión o absorción de rayos gamma, retrocede debido a la conservación del momento lineal, de la misma forma como retrocede un fusil cuando dispara una bala, utilizando cierta cantidad de energía [5]. Imagen tomadas de [6].

Así, si el rayo gamma emitido por el núcleo tiene menos energía de la necesaria para ser absorbido resonantemente por otro núcleo idéntico. De algún modo el rayo gamma emitido deberá tener una energía mayor de la necesaria para la transición energética, si desea compensar la energía perdida por su propio retroceso mecánico y el retroceso del núcleo que lo absorberá. Asimismo, como los átomos están oscilando debido al movimiento térmico aleatorio, la energía del rayo gamma tiene un rango de valores dispersos causados por el efecto Doppler [5].

Fig. 4 View of Sections 5.1–5.2, with general aspects of Mössbauer spectroscopy



Las variaciones en la energía del núcleo se deben a la interacción de este con la nube de carga que lo rodea y se denominan interacciones hiperfinas, estas interacciones son principalmente el corrimiento isomérico, la interacción cuadrupolar eléctrica y la interacción magnética hiperfina o efecto Zeeman nuclear, las cuales dan información sobre el entorno químico de los núcleos Mössbauer y de esta manera permiten hacer espectroscopía Mössbauer en las muestras bajo estudio que contienen los núcleos susceptibles de este efecto. El corrimiento isomérico surge como resultado de la finitud del tamaño del núcleo, lo cual implica que este posee una distribución espacial de carga. Esto implica que existe un potencial electrostático dentro de la estructura del núcleo con el cual los electrones pueden interaccionar. Si se tiene en cuenta que los electrones con momento angular orbital igual a cero (electrones que ocupan los orbitales *s*) tienen una probabilidad no nula de encontrarse dentro del núcleo (a diferencia de aquellos para los cuales *l=0*), entonces estos pueden interaccionar con este potencial.

Existe entonces una perturbación de primer orden a la energía del núcleo dada por:

$$E = \frac{2\pi}{3} Ze^2\langle R^2\rangle|\Psi_{n00}(0)|^2 \quad (1)$$

Donde *Z* es el número atómico del átomo Mössbauer, *e* es el valor absoluto de la carga del electrón, *R* es el radio del núcleo y $|\psi(0)|^2$

Fig. 5 View of Section 5.3 with the theoretical bases of the Mössbauer effect and hyperfine interactions

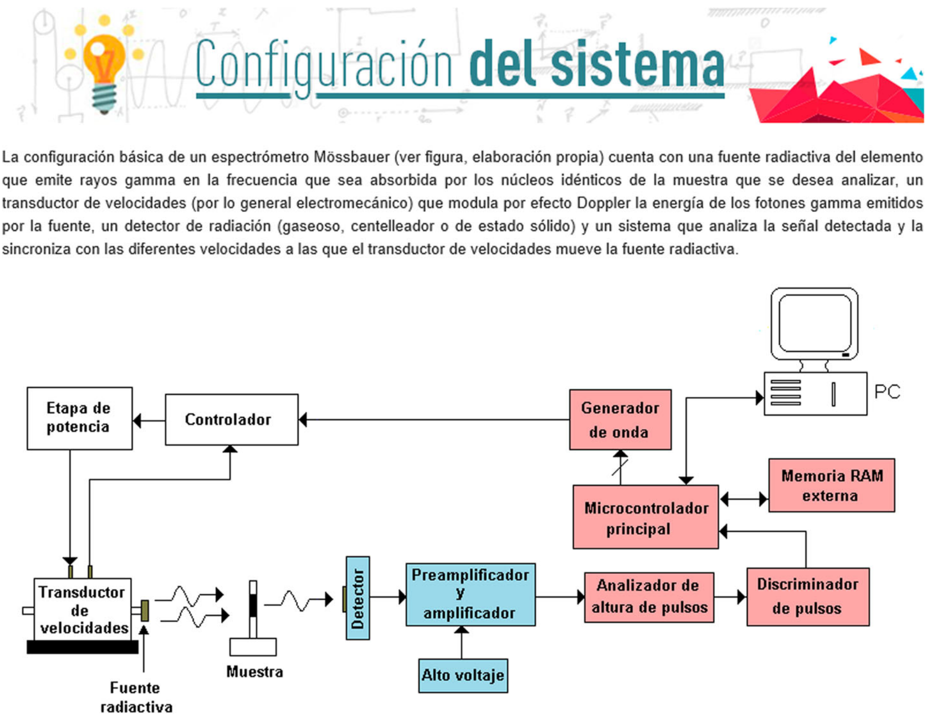


Fig. 6 View of Section 5.4 with the experimental configurations of the spectrometer

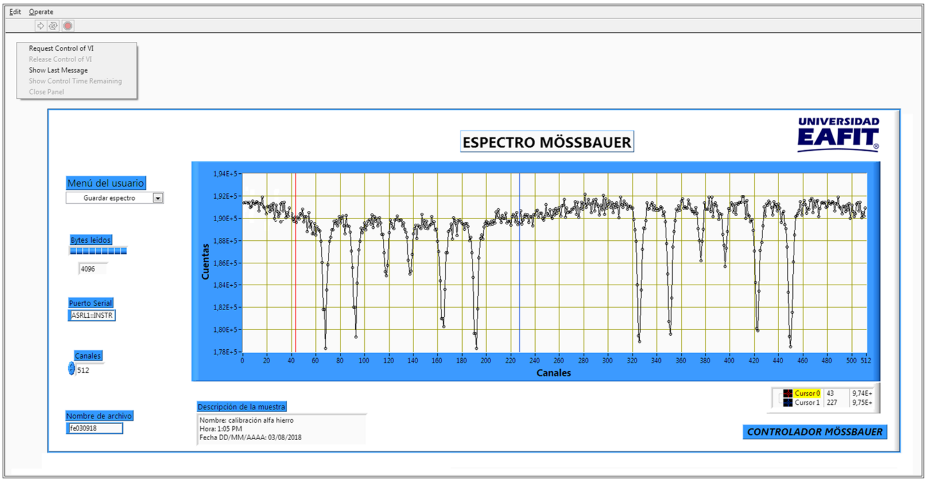
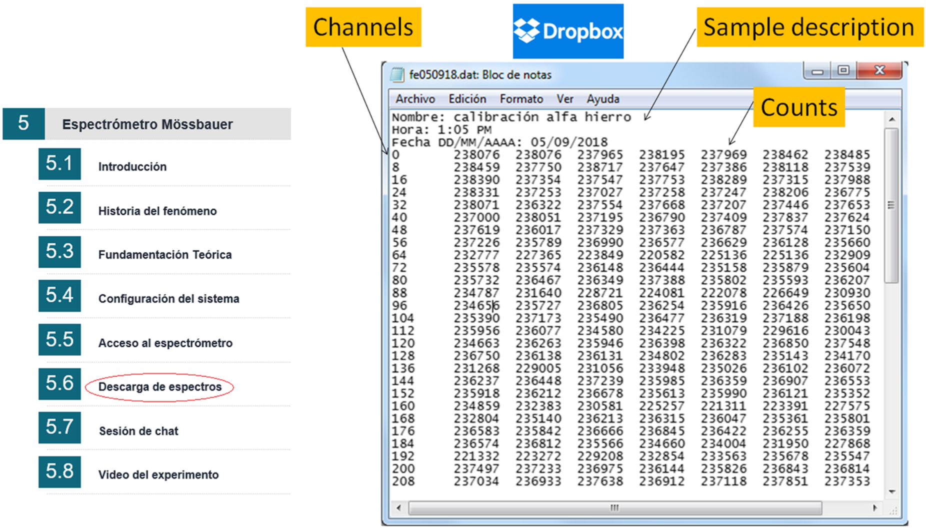


Fig. 7 Graphic interface developed in LabVIEW for remote control of the Mössbauer spectrometer of EAFIT University

labeled "Menú del usuario". In this menu it is possible to make three actions: 1. See a current Mössbauer spectrum, 2. Take a new Mössbauer spectrum and 3. Save the current spectrum in a file placed in a public folder in the cloud Dropbox. Before acquisition of a



(a) (b)

Fig. 8 **a** Section for spectra download **b** One of the formats with spectrum data

new spectrum, the user must assign a name to the file with the spectrum data by filling the field labeled "Nombre de archivo". In the field labeled "Información de la muestra" the user can include information of the sample, such as a name, hour of the spectrum acquisition starting and date of the experiment. These data will appear in the head of the file with the Mössbauer spectrum of the sample.

2.2.3 Access to the file with Mössbauer spectrum

As presented in Fig. 8a, the file with the data of the spectrum can be downloaded in Section 5.6. This file, with *.dat* extension, is generated in two formats; the first format contains two columns, where the first column contains the channels of the spectrum and the second one contains the intensity in counts; the second format contains nine columns, where the first column is the channel the following column contains the counts of this channel and the following seven columns contain the counts of the seven consecutive channels. The second format, presented in Fig. 8b, is used by least squares fitting programs such as MOSF [19]. Remote user can access and download the file with Mössbauer spectrum from a public folder placed in the Dropbox storage cloud. After registration, the administrator shares the folder with the user.

2.2.4 Interaction with the administrator of the platform

During the remote session, the user can interact with the administrator of the experiment through applications of chat and video. The chat session can be initiated by selecting the option labelled "Sesión de chat", available in Section 5.7, as presented in Fig. 9a. This section allows the user to formulate questions online and obtain response from the administrator of the experiment, helping to gain appropriation of the technique and solving doubts efficiently. A view of the chat session is presented in Fig. 9b.

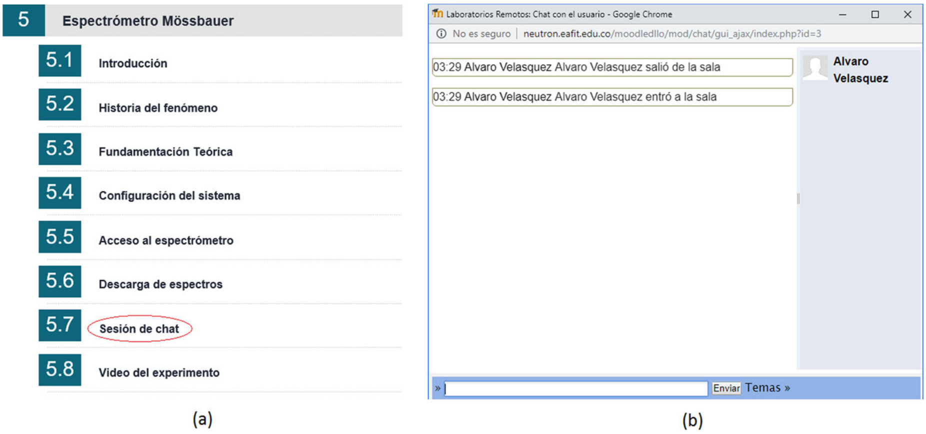


Fig. 9 **a** Chat tool of the remote platform, **b** Chat session for communication with the administrator

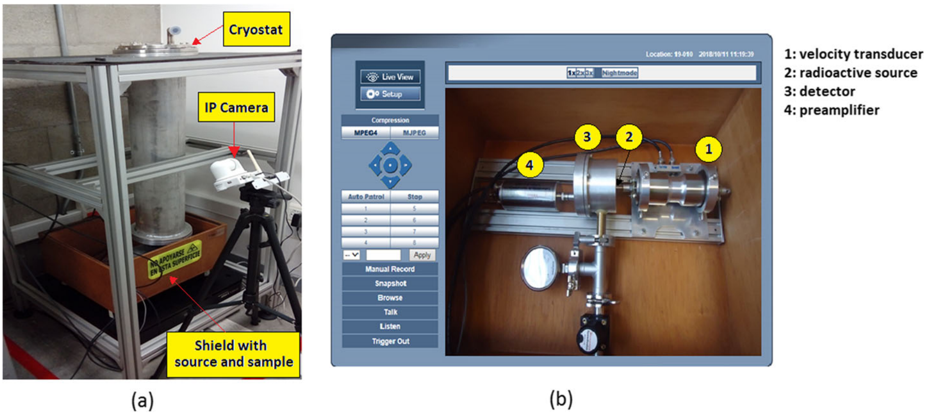


Fig. 10 **a** IP camera for video acquisition, **b** Video interface of the experiment

Remote platform also contains a tool for access to the video of the Mössbauer experiment, which can be accessed through Section 5.8, labelled "Video del experimento". For this purpose, we have implemented an IP camera, which can focus a view of the experiment. The camera has a fixed view for normal users, but it can be configured with the option of motion and focus of different views for users with administrator permissions if necessary. The camera also allows to enable microphone and speaker communication. Figure 10 presents a view of the IP camera, as well as the video interface accessible to the user.

3 Conclusions

We have implemented a platform for remote access to the Mössbauer spectrometer of the Instrumentation and Spectroscopy Laboratory from Universidad EAFIT in Medellín, Colombia. The platform was developed with the intuitive and friendly e-learning tool Moodle, allowing an efficient use of the radioactive source of ^{57}Co(Rh) of the spectrometer in periods where the staff of the laboratory is absent. The remote user can operate the spectrometer, download Mössbauer spectra from a public folder placed in the cloud Dropbox and interact with the administrator of the spectrometer through interactive tools as chat, video and voice. This tool can be a good option to introduce new researchers to the Mössbauer technique, as well as a way to share laboratory infrastructure for collaborative and interdisciplinary work.

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