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Virtual Laboratories in Physical Sciences : A Review

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Abstract. Integrating virtual laboratories as training platforms to complement teaching-learning processes in undergraduate and post-graduate courses becomes a necessity during this withheld face-to-face teaching context. The present article tries to introduce some useful websites that host physics experiments virtually. Some of them are based on the undergraduate and post-graduate curriculum framed by UGC and provide a simulation-based user interface that gives the student a feeling of doing experiments in the real physical laboratory. Some others give demonstrations and interactions of experiments that can be used by the teachers during their theory classes as well as lab demonstrations. Virtual labs give the students the freedom to access any experiment at any time from anywhere. Even though these virtual labs are not meant to replace the real physical laboratory, they are very useful for the teacher-student community to enhance their knowledge about the subject.
Keywords: Virtual labs, Online Labs, Physical Sciences Phet, Simulation.

1. Introduction

Teaching online is not generally accepted as a better way of teaching-learning process from years ago. But the covid-19 pandemic forced all of us to a sudden shift from offline classes and labs to online mode of teaching for the last one and half years. Each one of us was experimenting with available types of LMSs to find the most effective method for communicating the subject with our students. For teaching theory, many teachers succeeded in finding the online methods suitable for their topics even though we do not get complete satisfaction. Even before the pandemic situations, many institutions incorporated virtual labs as a tool to make transformations in the laboratory teaching-learning process. Virtual laboratories have been used as a complement learning resource to physical laboratories by students and teachers since 2000.[1] Virtual laboratories may be treated as Massive Open Online Courses (MOOCs) in ensuring the continuity of teaching. Studies on the increased effectiveness and efficiency of e-learning in the teaching-learning process with minimum connectivity issues have been reported recently,[2].[3]

There are a lot of sites which offers virtual labs or online labs. Doing experiments virtually seems like a matter which does not make any sense. Virtual labs cannot be treated as a platform that replaces real physical laboratories. But they can be used as a platform

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to introduce the lab session and also students can use it at any time anywhere. They can make mistakes and correct them, thereby become familiarise with the procedure for experimenting with the correct procedure in a real lab. But during this covid pandemic situation, virtual labs are really a blessing for the teaching-learning community.

Ministry of Education, Government of India initiated ICT-enabled virtual laboratories a platform which include 43 virtual laboratories with more than 360 experiments developed for various disciplines of science and engineering education.[3] Virtual laboratories act as a tool for distance learning and experimentation that provide users a comfortable environment to extend, improve, integrate, and assist the learning process of various subjects. Majority of teachers supported the role of virtual laboratories to enhance their teaching skills and help students to complete their laboratory practices without affecting the quality of learning,[12]

Learning or understanding science, particularly physics, accepted by society, as challenging since it involves a real understanding of basic concepts and principles behind most of the natural phenomena. Without having a base in fundamental concepts of physics, it is very difficult to follow theoretical as well as experimental physics in higher programs.[1] Just by reading a physics textbook, the student may not get a clear idea of the phenomena he/she is reading. Conventional method of teaching may not give the expected outcome from a learner's perspective. Physics teachers can effectively communicate the basic concepts with some simple demonstrations or experiments, so that the students get more understanding, and hence and he/she gets more enthusiastic about the subject.

The present article introduces various websites that provide online labs in physical sciences with a special focus on the labs developed with the assistance of the Ministry of Education, Government of India which that are useful for physics teachers and students for making teaching-learning process more interactive and informative.

2. Virtual Labs : An Initiative of Ministry of Human Resources, Government of India

Ministry of Human resources under the National Mission on Education through Information and Communication Technology (NME- ICT) in 2007 released a National Mission document:' *no talent of the country should be allowed to go waste*, through which they aimed at the use of e-learning technology to provide quality, equality and accessibility in education to every learner in the country.[3] The objective of this program was to develop virtual laboratories so that students in universities and colleges across India, who may not have access to adequate lab facilities or equipments. These virtual laboratories provide the user to conduct the physical laboratory experiments in a virtual environment with the help of a computer/laptop and an uninterrupted internet connection. Using virtual labs, the learner can perform the experiments and get the idea of a real experiment thereby increasing their curiosity. Through The Learning Management system of virtual labs, students are able to find various tools for learning including additional web resources, videos, animated demonstrations, and self-evaluation.

The main website of virtual labs is www.vlab.co.in.[3] The experiments based on various disciplines of science and engineering was developed by 11 reputed institutions in India, namely IIT Delhi, IIT Kapur, IIT Bombay, IIT Madras, IIT Kharagpur, IIT Guwahati,

IIT Roorkee, IIIT Hyderabad, Dayalbagh University, and Amrita Vishwa Vidyapeetham University. Each of these institutions developed virtual experiments in the disciplines sanctioned to them by MHRD and these experiments are available under the broad Engineering and science disciplines: Electronics and communication engineering, Computer science and engineering, Electrical Engineering, Mechanical engineering, Chemical engineering, Biotechnology biomedical engineering, Civil Engineering, Physical Sciences, and Chemical Sciences.

We are more interested in the virtual labs on physical sciences. The virtual labs on physical sciences were developed by Amrita University is now available on the main website www.vlab.co.in and also on their home site www.amrita.vlab.co.in.[4] Some basic physics and astrophysics experiments developed by IIT Kanpur are also available in the mail site ww.vlab.co.in. This article aims to introduce the list of experiments in all these sites in the coming sections. The virtual labs developed by Amrita university allow the students to access it from anywhere at any time. All the experiments developed include parameters that are not available in a real-world physical laboratory. For example, if the student wishes to know what happens to the oscillations of a compound pendulum if it is taken to another planet or moon, he can experience the result by changing the environment of the experiment to the moon or the planet. These labs are useful not only for normal students but also for those with learning disabilities or other physical disabilities.

Most of the experiments designed can be utilized as a tool for explaining basic concepts of physics in theory classes too. For example, in the simulations of Millikan's oil drop experiment, the forces affecting moving particles in an electric field is presented in a very simple way. The virtual version of this experiment include magnified view of the chamber used to suspend particles, allows to view the fall of droplets as a function of applied voltage and measure the rate of fall between the cross-wires using the timer, can see the ionization of air from the x-rays and its impact on the oil droplets. There is the option for repeating the process with glycerine and oil droplets and learn the differences. These facilities are there for most of the experiments.

To share high quality laboratory resources, selected institutes can participate as a virtual lab nodal center for the effective usage of Virtual Labs in their curriculum. It is an exciting new venture which allows institute to use virtual labs for the benefit of their students and teachers. It provides a platform for everyone to contribute towards the future development of Virtual Labs . There is no registration fee for this program. The main advantage of becoming a nodal centre is that the faculty could manage the lab sessions of each class more effectively like a class room. More information about nodal centre is available in the website itself.

2.1. List of labs and experiments in Amrita Physical sciences Virtual Lab —

2.1.1. Heat and Thermodynamics lab—Thermo Couple-Seebeck Effect, Thermal conductivity of bad conductor, Lees Disc Experiment Newtons Law of Cooling, Black Body Radiation, Stefan-Boltzmann Radiation Law, Study of Phase change, Heat transfer: Conduction, Convection, Radiation

2.1.2. Harmonic motion and Waves Lab—Doppler Effect, Melde's String experiment, Ultra sonic Interferometer, Velocity of sound and compressibility of liquids, Kund's tube apparatus, Astable multivibrator using transistor, Monostable multivibrator, Bistable multi

vibrator, Astable multivibrator using IC 555

2.1.3. Modern Physics Lab —Franck-Hertz experiment, Millikan's oil drop experiment, Emission spectra, Solar panel experiment (Remote trigger), Soldering (Remote trigger), Planck's constant determination, Abbe's refractometer, Photo electric effect

2.1.4. Optics Lab —Resolving power of a spectrum, angle of the prism using spectrometer, Spectrometer i- i' curve, Spectrometer i-d curve, Spectrometer: Determination of Cauchy's constants, Refractive index of the material of a prism, dispersive power of a prism, Diffraction grating: wavelength of spectral lines.

2.1.5. Laser Optics Lab—Laser beam divergence and spot size, Numerical Aperture of Optical Fiber, Michelson's Interferometer: Wavelength of laser beam, refractive index of glass plate, Brewster angle determination, Verification of Malus law, Newtons Rings: Wavelength of light, Refractive index of liquid

2.1.6. Advanced Mechanics Lab—Compound pendulum- Symmetric, Kater's Pendulum, Young's Modulus of the material of rectangular bar by Uniform bending, Young's Modulus of the material of rectangular bar by non-uniform bending, Moment of inertia of a torsion pendulum, Rigidity Modulus of the suspension wire of a torsion pendulum, Rigidity Modulus of the material of a rod - Static torsion

2.1.7. Solid State Physics Lab—Hall Effect, B-H Curve, Cornu's Experiment for the determination of Y, n and s, Zener diode as a Voltage regulator, Crystal Structure, Characteristics of Zener diode, Resitivity four probe method, Characteristics of a thermistor

2.1.8. Mechanics Lab(pilot)—Elastic and inelastic collision, Projectile Motion, Collision balls, Ballistic Pendulum, Newton's Second law of motion, Moment of Inertia of a Fly Wheel, Torque and angular acceleration of a fly wheel, Torsional oscillations in different liquids

2.1.9. Electric Circuit(pilot)—Parallel RC Circuits, Parallel LC Circuits , Thevenin's Theorem, Series RL circuits, Norton's Theorem, Series LCR Circuits, Kirchoff's Laws, Series RC Circuits, Parallel LACR Circuits, Parallel RL Circuits

3. Basics of Physics Lab Developed by IIT Kanpur

This is a newly developed lab prepared by IIT Kanpur as a part of virtual lab project of MHRD with an intension to make the learners to understand analyse the basic concepts of physics and mainly intended for BE or B,Tech students of engineering physics. This lab is available in the main vlab site and also in https://bop-iitk.vlabs.ac.in/basics-of-physics.[6] This lab include 10 experiments mainly Carey Foster's bridge to measure specific resistance of material, Energy band gap of semiconductor, Radiation with temperature change using Stefan's law, Finding viscosity of liquid by rotations cylinder method, Measurement of wavelength of monochromatic source of light with the help of Fresnel's Bi prism, Measurement of focal length of the combination of lenses separated by a distance, To measure specific rotation of cane sugar using Polari meter, Measurement of high resistance by the method of leakage of condenser, To study polarization of light using He-Ne Laser, Measurement of numerical aperture and attenuation constant of optical fibre.

4. Virtual Astronomy/ Astrophysics Labs Developed by IIT Kanpur

The astronomy/astrophysics labs are developed by IIT Kanpur for students studying an introductory course in astrophysics and astronomy.[5] This lab is also hosted in the main site as well as in http://va-iitk.vlabs.ac.in . All the experiments in this lab can be done using Stellarium which is a free open source planetarium software to conduct all the experiments. Hence students are required to download the software before starting the experiments. There are 14 experiments listed under this virtual lab. They are as follows: familiarization with the astronomical objects visible to naked eye in the night sky, familiarize the Constellations in the night sky, identify the retrograde motion of Mars with respect to the Background stars, identify the prominent spectral lines in the spectrum of our sun, get familiarized with the spectra of different stars, extract coordinates of a star assuming a telescope in equatorial mount, learn the concept of sidereal time, to measure astronomical distances using Cepheid variables, measure the Proper Motion of Barnard's Star, identify a Circumpolar Star, determine the distance and age of cluster using Colour Magnitude Diagram, determine Orbital Inclination of the planet Mars, measure planetary distances, measure distance to the Moon and to determine observer's location by means of the stars

5. Online Labs – Initiative of MHRD for School Students

Another useful site for physics experiments is www.olabs.edu.in . This site is as an educational initiative of Ministry of Electronics and Information Technology, Government of India, developed by Amrita university centre for research in advanced Technologies(AMRITA-CREATE) in partnership with CDAC Mumbai.[7] This online lab site hosts experiments in Physics, Chemistry, Biology, Mathematics and English for the students from classes 9 to 12 based on NCERT/CBSE/State Board syllabus. The online labs also give students the experience of doing real lab by recreating a laboratory and its equipment, using visual simulators. The experiments also help teachers assess a student's observations, procedural skills, and track student usage through interactive activities, videos and animation. Even though these labs are intended for high school teachers and students, most of the experiments in physics labs can be used for teaching in theory classes or demonstrating experiments for first and second year undergraduate students of physics main and physics complementary courses. The list of experiments that can be used for teaching under graduate students are given below. All these labs include videos that explains the procedure of the experiment in real labs.

5.1. List of Experiments—Ohms law- Determination of unknown resistance, verification of Ohms law, Potentiometer- internal resistance of a cell, and comparison of emfs, Figure of merit of a galvanometer, conversion of galvanometer to ammeter, AC sonometer, Liquid lens- refractive index of a liquid, Meterbridge- resistance of a wire and verification of law of combination of resistances, Diode characteristics, Zener diode characteristics, transistor characteristics, Measurements using Screw gauge, Vernier calipers, and spherometer, acceleration due to gravity using simple pendulum, Viscosity of a liquid-Stoke's method, Spring constant of a helical spring, Surface tension- capillary rise method, Youns modulus- Searle's method, Resonance Column, Sonometer, Newton's law of cooling, verification of Hookes law, Belljar Experiment .

Upon using these site, students will be able to perform, record and learn experiments - anywhere, anytime, and the site gives individualized practice in all areas of experimentation. These online Labs had been selected as a leading Digital India initiative in the category Empowerment for Good Governance in 2015. On that day Shri Ravi Shankar Prasad, Minister of Communications and Information Technology, launched the nationwide rollout of Online Labs for School Experiments.

6. Other Available Virtual Labs for Physics

6.1. LTspice simulator for Electronics Lab—LTSpice is a free circuit simulator from the manufacturer Analog Devices that uses a mixture of Spice commands and circuit diagrams with a sizable library of passive and active components.[8] The software uses an embedded window for the circuit space, drawings for new parts, and the embedded "oscilloscope". There will be no schematic loaded from starting the program, so a new one has to be made by clicking the icon under File to start a new circuit draft or using the File drop-down menu. The main tools used in this program are listed under File, View, Tools, and Help. One can hover over the toolbars to see what function they provide. This can be downloaded from the site https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html

6.2. The PhET Interactive Simulations project—An interactive simulations for science and mathematics is hosted in the site https://phet.colorado.edu.[9] This site was founded in 2002 by Nobel Laureate Carl Wieman, at the University of Colorado The Phet Project engages students through an intuitive, game-like environment where students learn through exploration and discovery by providing fun, free, interactive, research-based science and mathematics simulations. This site covers broad areas of physics which are useful mainly for teaching theory classes online for UG and PG students. These simulations helps to effectively communicate the concepts of physics with students. The site provides a video on how to use the site for our online classes. The objectives of the PheT project include providing interactivity, making the invisible concepts visible, show visual mental models and also to creat a simulation that can be flexibly used in many educational situations.

6.3. myPhysicsLab—Another interesting site for experimenting with physics concepts is http://www.myphysicslab.com which is an open source software under the Apache 2.0 License. Source code is also available at Github.[10] There are almost 50 different simulations in the source code, each of which has an example file which is mainly for development and testing. These can also be used to show simulations offline (when not connected to the internet). Most of the simulation web pages show how the math is derived. A physics simulation starts with a mathematical model whose variables define the state of the system at a given time.

This opencode software is developed by a single person Erik Neumann, living in USA who is a self employed engineer. He started developing this website in 2001, both as a personal project to learn scientific computing, and with a vision of developing an online science museum. All the physics simulations based on a set of differential equations that tells how the variables evolve over time. The forces and the geometry determine the equa-

tions. All the simulations developed in this site is very much useful for providing conceptual knowledge to our students especially in this pandemic time. These animations can be used for teaching theory especially for first year UG physics students and complementary physics

7. Conclusion

The rapid spread of Covid -19 pandemic followed by the lockdown policies taken by various governments extremely affected the education system all over the world. All educational institutions are obliged to follow online mode of education from 2019 march onwards. A lot of online learning management systems are available in internet, may be from 2000 onwards. But most of the educational institutions in India, especially in Kerala, are not familiar with the online LMS platform before this pandemic era. The extensive use of these LMS increased exponentially during the last two years after Covid spread. Even though, theory classes can be conducted online mode, educational institutes still facing problems in conducting laboratory classes. The LMS that provides virtual laboratories plays an important role now. The virtual lab site launched by MHRD, Government of India gives a user friendly platform for undergraduate and post graduate students. They provide an easy platform for the teachers to conduct labs sessions in a regular manner. Most of the universities took the decision to conduct the practical examination internally. In that case, virtual lab platforms is option for teachers to conduct lab examinations considering the existing Covid protocol and hence can evaluate students on the basis of their online performance. I am suggesting this, only because of the current situation, accepting the fact that virtual labs cannot replace real lab sessions in any context. This article mainly intended to introduce various online sites that hosts virtual laboratories that are useful for teachers and students of physics community. The olabs and vlabs developed by Amrita university seems to be more useful for conducting lab sessions in online mode. Other sites can be used for teaching theory. LTSplice software can be used for performing electronics laboratory.

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