

MS-Excel Spreadsheet Applications in Introductory Under-Graduate Physics-A Review

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Abstract: The role of information technology has been quite instrumental in bringing improvisations in the the field of pedagogy. The institutions are shifting to ICT based techniques, because teaching science subjects with ICT based simulations has partially replaced the requirements of laboratories along with enhancement of conceptual understanding of the students. Presently, many science teachers prefer to use self made spreadsheet computer simulations and virtual laboratories. For example, the most common MS-Excel spreadsheet can be programmed to imitate the movement of many physical systems such as a motion of projectile, trajectory of charged particle in electric and magnetic fields; and motion of particle in a box. Excel spreadsheet is frequently available on desktop computers, and because of their massive data manipulation functions and powerful plotting facilities they are finding increasing use in physics teaching. This review paper highlights the role of MS-Excel spreadsheet in simulating many real world problems in the teaching of Physics.

Keywords: Spreadsheet, MS-Excel, Simulation, Physics Teaching

I. Introduction

Initially spreadsheets have been used by accountants for many years. In the realm of accounting jargon a "spread sheet" or spreadsheet was and is a large sheet of paper with columns and rows that organizes data about various transactions. On the other hand, in the era of ICT, counterpart of this rudimentary paper sheet is "Electronic Spreadsheet" [1]. An electronic spreadsheet organizes information into software defined columns and rows. The spreadsheet program summarizes information from many sources in one place. This information could be processed with spreadsheet functions to help a decision maker to take the most suitable decision. Although there are many electronic spreadsheet softwares, but the most commonly used one is MSEXCEL from Microsoft Company. MS-Excel was one of the first spreadsheets to use a graphical interface with pull down menus and pointing device - mouse. The Excel spreadsheet with a graphical user interface was easier for most people to use than the command based spreadsheet products. Endowed with multiple features, Excel spreadsheet is economical and easily available software to simulate the real life problems in the field of science.

The simulation is becoming an indispensable tool in the hands of teachers and these techniques are used by many educational institutions in the teaching of science subjects. Simulation is basically in the form of a small computer program with graphical interface, developed to reproduce the operation of a real physical system - both numerically and graphically. Thus use of simulation in teaching science subjects could partially replace the requirement of laboratories at introductory level. Although simulation cannot replace a real physical laboratory experimental activity, still it has several advantages - such as easily available spreadsheet softwares at reduced rates for multiple copies, substitute for experimental kits due to their non-availability and many more. In the market, there are many powerful commercial packages available for simulation. However, these packages are very costly. For example, MATLAB is a comprehensive package with multiple features like computation, visualization and

programming. Generally these commercially available packages are costly. Comparatively, spreadsheet (MS-EXCEL) is equally powerful and economical. Its features such as- a large number of functions to do mathematical, statistical, database, date/time, financial and other calculations; charting and graphing; and automation through script language (VBA) - make it inevitable pedagogical tool in teaching of Physics. In particular, this paper presents the contribution of spreadsheet (MS-EXCEL) in teaching Physics.

II. Spreadsheets in Physics

Teaching of Physics has also been on change for the last two decades or so. The use of internet and simulation has made the class room environment more interesting and effective. Simulation is used to teach many concepts of Physics [2–4]. By integrating computational physics techniques with simulation and traditional teaching learning methods of Physics, a major improvement in the conceptual understanding of students is expected [5–7]. Spreadsheet programs are well equipped with trigonometric, exponential and logarithmic functions along with arithmetic, relational and logical operators for combining these functions. As a result, spreadsheet is convenient and handy tool for carrying out many types of calculations that occur in General Physics, Quantum Physics, Electronics, Electrodynamics and Nuclear Physics. In addition to their applications in Physics education, spreadsheets have also many applications in the education of Mathematics [8–18], Chemistry [19], Bio sciences [20] and Engineering [21]. Furthermore, due to integrated VBA programming environment and powerful plotting facilities, the spreadsheets make it easy to display and use the results of such calculations. There is more freedom of varying the parameters in calculations and instant result is available both in numerical and visual forms. There are many papers highlighting the applications of spreadsheets in education, in particular Physics [22–29].

In the subsequent sections, a synopsis of spreadsheet applications in introductory Physics is presented.

2.1 Applications in General Physics

Spreadsheet is used as an important pedagogical tool in Mechanics due to its computational and graphical functionalities. In reference [30], the author has presented the study of 1-dimensional motion when object is dropped from certain height. Ionel Grigore et.al [31] demonstrated the vertical motion in earth's gravitational field. The spreadsheet developed analyzes the motion of a spherical body launched vertically when air friction is not considered, to the movement of the same body when both air friction and the buoyant force are taken into consideration. The authors of reference [32] used interactive spreadsheet to explore the damped harmonic oscillations. Himawan Putranta and Heru Kuswanto [33] demonstrated the formation of Lissajous figures and shape dependence on amplitude, wave number and frequency. The authors of [34, 35] have constructed spreadsheets to investigate the motion of the projectile both in vacuum and air. The article [36] presents a method of solving the problem of planetary motion. A spreadsheet application is presented that simulates the motion by solving the azimuth equation numerically without using programming. The authors of [37] have presented a study of relativistic kinematics using Excel simulation. In article [38] the authors have demonstrated the study of the oscillatory movement of a mass-spring system to illustrate the use of differential equations for the simulation of physical situations using a spreadsheet.

2.2 Applications in Quantum Physics

This is true that teaching and understanding of Quantum Physics at introductory level is difficult. It involves large numbers of mathematical functions and equations the students are not used to. However, the spreadsheet simulations have strongly supported the improvement in the learning and cognitive thinking of the students [39]. In this reference efforts have been made to investigate functional understanding of the concepts of wave group, wave function, probability density plots. The results of this study strongly support the fact that spreadsheets in cooperative group learning help students confront their cognitive constraints and foster a functional

understanding. Simulation to study the dynamic behavior of Simple Harmonic Oscillator (SHO) using spreadsheet software is also presented by the same author in reference [40]. In this article efforts have been made to generate spreadsheet for wave functions and probability density curves of quantum harmonic oscillator. The uncertainty principle and Gaussian packet are explained using Excel spreadsheet simulations in article [41] by Popat S. Tambade.

2.3 Applications in Nuclear Physics

Teaching of Nuclear Radioactivity is somewhat difficult to under-graduate students. In many cases, students are not used to many mathematical equations and lack the understanding necessary for interpreting those equations. In these cases simulation comes as a handy tool. Also the use of radioactive material in the classroom is not always practical or advisable. Therefore modeling radioactive decay is good substitute. In the reference [42], the concept has been discussed in details. The radioactivity has been simulated in EXCEL environment. The decay law $N(t) = N_0 e^{-\lambda t}$ and significance of decay constant λ are demonstrated in the class room environment. To illustrate, example of radioactive decay is reconstructed as described by author of reference [42]. The major assumption to define decay is that the occurrence of desired number by random number generator is linked to the decay of atomic nucleus. There are many problems in Nuclear Physics which also find place in other branches of Physics. These are mentioned in earlier sections. The summary presented here is not exhaustive and other applications of spreadsheets are in aerodynamics [43, 44], fluid mechanics [45], and in thermodynamics [46–49].

In this article only those applications are considered which are generally found in introductory physics at first level.

III. Conclusion

The simplicity of spreadsheet programs, in addition to their rich library of built-in functions, plotting capabilities, and integrated programming environment (VBA), has made them an attractive tool for education in sciences and other disciplines. The increasing number of simulations in teaching Physics shows that these have profitable effect on the minds of Physics learners. Based on above study following important conclusions can be drawn:

- There are very powerful commercially available simulation packages, but at the same time their cost is considerably high and cannot be afforded easily. Most of the physics experiments can easily be simulated by developing low-cost spreadsheet (e.g. MS- Excel) based simulators.
- Simulation based experiments could be performed away from the real physical laboratories, thus virtually replacing the requirements of expensive experimental kits.
- Simulation of radioactivity is indispensable recipe because it would save the students from the hazards associated with radioactive materials.
- This approach is suitable for students who are weak in mathematics, for example, many students who are majoring in chemical sciences, biological sciences, etc. Spreadsheets generate approximate numerical solutions and graphical descriptions to develop a qualitative appreciation of complex physics concepts.
- Spreadsheet modeling could be integrated with laboratory practice into undergraduate education physics curriculum to get better results.
- Spreadsheet simulation could enhance the conceptual understanding of the learners.
- Use of spreadsheet simulation would horn the mathematical and programming skills.

- In the end, the students who want to opt the career in Physics should try out analytically tedious or impossible problems. Consequently, they would be able to understand the limitations of analytical methods and appreciate the importance of adopted computational methods used for simulation. Such an insight would motivate the students to probe deeper into the physics concepts being taught to them and train them to solve more realistic and research oriented problems. The adoption of this kind of teaching learning approach could go a long way in inspiring the students to choose a future in physics.

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