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Design And Implementation Of A Simple Apparatus For Teaching Dynamics In Physics

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Abstract

We present the design and construction of a novel Dynamics Teaching Aid that makes teaching and learning of dynamics in secondary schools rather easy and interesting for both teacher and student by exploring the advantage of visual learning. This apparatus presents certain advantages in our local teaching environment as it does not require rigorous training to be used by teachers; can be easily mass- produced for local use at highly reduced cost and does not depend only on public electric power supply for its operation. Its precision in explaining the physical concept of certain quantities in dynamics such as velocity and acceleration marks the hallmark of our design concept.

Keywords: Engineering Design Techniques, Teaching, Dynamics, Velocity, Acceleration

1.0 Introduction

In secondary school education, certain science subjects have proven more difficult to comprehend by students and several teaching techniques have been developed to improve their understanding. Physics, a major science has the potential to prove rather difficult to understand by students. (Reddish 1994) explained that students consider physics a difficult subject because Physics as a discipline requires learners to employ a variety of methods of understanding and to translate from one to the other — words, tables of numbers, graphs, equations, diagrams, maps. Physics requires the ability to use algebra and geometry and to go from the specific to the general and back. This makes learning physics particularly difficult for many students. (Ornek, Robinson, and Haugan 2008) concluded after their survey on "what makes physics difficult?" that faculty members should learn how to reach their students and how to make physics concepts be understood by their students even if they are really sophisticated in their field. The structure of physics as a physical and natural science indicates a need for experimental ways of teaching and dealing with its subject matter. In this respect, we present the design and construction of a simple dynamics teaching aid. It is aimed at rendering experimentally and vividly to students the concept and relationship between certain quantities like velocity, distance and time. This work originates after a careful study of teaching techniques and an effort to apply engineering designs to further enhance teaching and learning of physics in secondary schools.

2.0 Literature Review

In this section, we begin our research by identifying those techniques that have produced remarkable results on the performance of students across various subjects including physics. We try to find an intersection between productive teaching techniques and the use of well designed teaching aids. There are numerous works on various teaching techniques in literature. The most popular is the constructivist technique. Constructivism is a theory of knowledge that argues that humans generate knowledge and meaning from their experiences (Wikipedia, 2010). Students are not a blank slate and knowledge cannot be imparted without the child making sense of it according to his or her current conceptions. Therefore children learn best when they are allowed to construct a personal understanding based on experiencing things and reflecting on those experiences (Liepolt, 2004). Furthermore, this theory reveals that certain activities are primarily encouraged in a constructivist classroom, these are:

i. Experimentation: Students are exposed to experiments and made to discuss together as a class

ii. Research Projects: students research a topic and can present their findings to the class.

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iii. Field trips: this allows students to put the concepts and ideas discussed in class in a real-world context.
iv. Films: these provide visual context and thus bring another sense into the learning experience.
v. Class discussions: this technique is used in all of the methods described above. It is one of the most important distinctions of constructivist teaching.

Kim (2005) in a research work on the effects of constructivist teaching approach concluded after series of experiments that constructivist teaching is more effective in terms of academic achievements of students and also, students have some preference for a constructivist teaching classroom environment. On the other hand, critics have voiced certain arguments against the constructivist based teaching method with claims that they are either misleading or contradict known findings (Anderson, Reder and Simon, 2000). Supporters of constructivism rather argue that students' especially elementary school-aged children are naturally curious about the world, and giving them the tools to explore it in a guided manner will serve to give them a stronger understanding of it (Liepolt, 2004).

(Mayer, 2004) developed a literature review spanning fifty years and concluded that the constructivism pertaining to hands-on activity is a formula for educational disaster. His argument is that active learning is often suggested by those subscribing to this philosophy. Mayer recommended using guided discovery, a mix of direct instruction and hands-on activity, rather than pure discovery. Kirschner, Sweller, and Clark (2006) agreed with the idea of constructivism by arguing that learners construct knowledge but their work further supports instructional design recommendations of this theoretical framework. They claim that the constructivist description of learning is accurate, but the consequences of giving instructions as suggested by constructivists do not necessarily follow. The potential benefits/limitations of constructivist teaching approach is to a large extent based upon the large number of varied personal characteristics and opinions as well as the prevalence of different learning problems in children today.

Other teaching techniques like the Montessori Method stress the development of initiative and self-reliance by permitting children to do by themselves the things that interest them within strictly disciplined limits (Wikipedia, 2010). The instruction method comprises of both direct and indirect instruction methods (Adprima, 2010). In direct teaching or classical teaching, specific learning targets are set. Students are told reasons why content is important. This technique is suited for teaching specific facts and basic skills. Its disadvantage is that it stifles teacher creativity and requires well-organized content preparation and good oral communication skills. The indirect teaching rather encourages cooperative learning, lecture with discussion, brainstorming and use of video tapes/slides (Adprima, 2010). This technique is closely related to the constructivism approach to teaching and learning.

Though identifying the best way of teaching might still remain an issue of contention amongst educationists as revealed in the above reviews, it is arguably correct that finding ways of integrating engineering designs with effective and productive teaching techniques will go a long way in enhancing teaching and imparting knowledge on the students. This was substantiated in the work of Adeyanju (2003) which concluded after carrying out a case study of Winneba Basic and Secondary School in Ghana, that teachers, whether those on training or those with qualifications, perceive the use of learning aids in teaching as advantageous to the teacher and to the students. The use of Teaching Aids reduces the talk and chalk method of teaching and identifies that teachers are compelled to improvise teaching aids for their teaching due to its unavailability.

In general, it is particularly accepted that Human beings unlike other animals try to be sure of anything they do. They therefore try to get a datum to which every other thing can be compared or identified with. It is therefore on this argument, and having identified a need for improved teaching aids, that visualization has been identified as a long lasting means of learning. With advancements in engineering designs, several modern teaching aids especially visual aids have revealed how engineering design concepts have found relevance in enhancing teaching and learning in schools and universities. Undoubtedly, many of these engineering teaching aids have greatly advanced man's ability to easily understand but most times, insufficient financial investments in purchasing these aids predominantly in developing societies has been identified as a significant drawback to productive learning. The cost of acquiring these modern teaching aids has constituted a disadvantage particularly in Nigerian secondary schools. There is therefore a need for engineering designs to cut down on both design complexities and financial cost by using locally sourced materials. Having identified physics as a subject particularly inclined to the use of teaching aids for its understanding, and dynamics as a key subject matter, we carried out a light survey to identify the availability of this teaching aid in our local secondary school environments in Minna, Niger state, Nigeria. We identified the lack of such a teaching aid and hence the motivation for this work. We were motivated to make designs for our local environment that comfortably integrates a drastic reduction in financial cost with a strong inclination towards visual teaching to improve the learning of dynamics in senior secondary schools.

3.0 Dynamics Teaching Apparatus

This Section presents the design and operation of the apparatus. The block diagram is as shown in Figure 1.

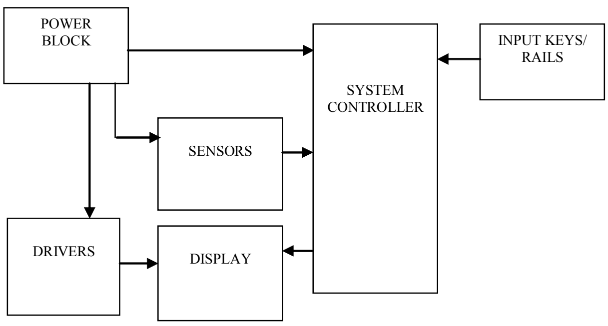

Figure 1: Block diagram of the system

3.1 Design

The power supply unit consists of a step down transformer, bridge rectifier and an LM 7805 for voltage regulation. The transformer steps down the ac mains from 240V to 12V. The value of each power component was designed to ensure optimum performance. We present detailed mathematical design calculations below that resulted in the choice of a 1000µF filter capacitor that gives a ripple free dc output voltage. A supplementary dc battery source provides power supply in the absence of the ac mains.

For a full wave rectifier design,

t = 1/2,

where t is time cycle and F is frequency of signal.

For Nigeria power supply frequency, f = 50Hz.

$$t = \frac{1}{2 \ x \ 50} = 0.01s$$

For V_{rms} *of 12v,*

Vp = √2 x 12 = 16.97v,

where Vp = peak Voltage.

But ripple voltage for full wave rectification is about 48% of the peak value,

Therefore, (48/100) x 16.97 = 8.15v

Using, Q = CV = it,

where Q = charge, C = capacity, V = voltage, i = current and t = time.

C = it/V = (500mA x 0.01)/ 8.15 = 613µF

For better ripple correction, a higher capacitance value ensures a better dc output. Therefore, for an almost constant dc source, a capacitor value of 1000µF. Choice of this value gives us a ripple voltage of about 5v as obtained below.

∂v = i∂t/c = (500mA x 0.01)/ 1000µF

However, the maximum rectified output voltage reaching the regulator is obtained as follows:

16.97- 2 x 0.7 – 5 = 10.57v

The drop of 1.4V arises as a result of potential drop across the two conducting diode in each half of the rectification cycle. This arrangement ensures that twice the desired output is available for the regulator. A heat sink was attached to the regulator to avoid excessive heating and consequent breakdown. Figure 2 is a schematic diagram of the power supply circuit.

The sensor block consists of two sensors namely sensor A and B. They are similar in physical and electrical characteristics. They are Light Dependent Resistors (LDR) that respond when a laser beam falls on them resulting in a reduction in their internal resistance value. Laser beam was chosen because of its ability to produce a monochromatic light. The

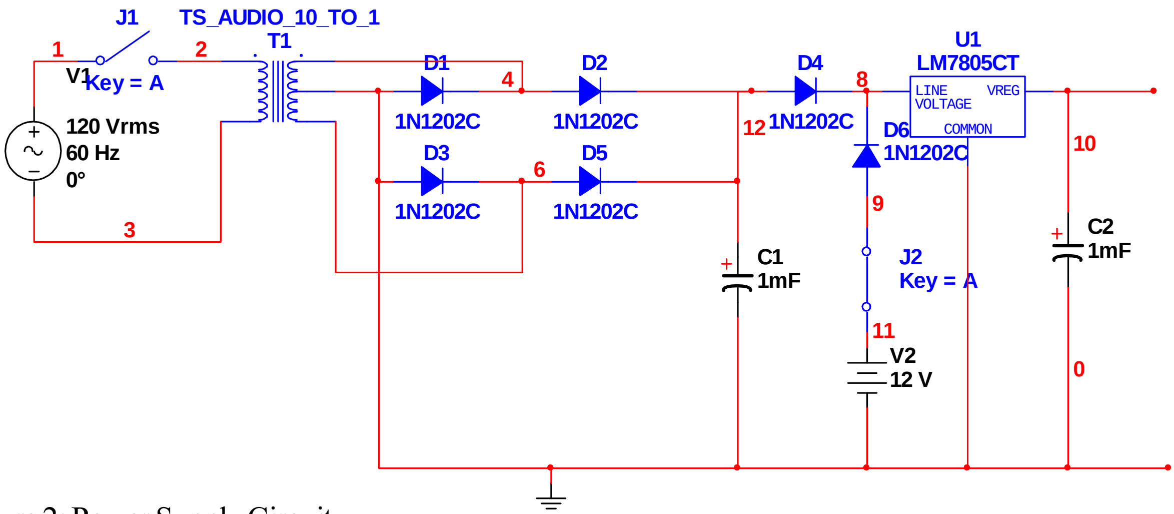

Figure 2: Power Supply Circuit

user input keys consist of 10 normally open toggle switches, among which 5 are used to select predefined distances of 20,40,60,80 and 100 cm respectively. A dedicated switch is provided for any distance of choice but preferably within the stipulated range of 1m because of physical design constraints. There are 3 other switches used to display any of the three parameters: time, velocity, and acceleration and lastly, a switch to serve as a reset button.

The microcontroller is a single chip microprocessor used for computation and display of the various parameters. The AT89C51 was incorporated with a 12MHz crystal oscillator whose function is to generate the system clock pulse, thus making the system operate at approximately 1Million instructions per second (1MIPS). The controller was programmed to execute the following:

i Ensure that the keypad scan routine continues until a key representing a distance of interest is pressed which determines the value the microcontroller will use in its calculation.

ii Ensure that once the device is switched on, the controller is kept waiting for a distance to be chosen.

The display unit consists of a common anode seven-segment display. It is powered appropriately to ensure correct display of digits. This display could be to four significant figures because the display is made up of four digits. To make and break the current reaching the different segments of the seven segment display, four PnP transistors (2N 3906) were used to effectively drive the display. The common anode was chosen in preference to the common cathode type in other to ensure that the system runs as a current sink and not as a current source. This is to avoid heating up of the microcontroller. The four seven-segment displays were all multiplexed to reduce the number of input-output pins required to interface the different displays with the microcontroller. By energizing the proper pins with a proper d.c voltage level subsequent LEDs can be energized to achieve the desired number to be displayed.

A smooth rail of about 1.2 m is attached to the entire system. The rail is the pathway designed to provide a channel of movement for a roller (a small ball) that will be used to simulate a moving object. It is graduated for a maximum distance of 1 m. Sensor A is fixed at zero mark (origin) on the rail, while sensor B is made movable to any distance of choice within the limits of the rail.

3.2 Operation

The operation of this apparatus is controlled by the System Controller, which is a microprocessor unit (AT 89C51) as described earlier. At the start of an experiment, the device is switched on; a distance of interest is selected on the key pad, which is automatically recorded by the system controller; sensor B is moved on the rail to the position of the selected distance; then, a roller is gently dropped in the rail before the position of sensor A (the origin of the calibrated distance), to move between the sensors thus blocking the signal generated by the transmitter from reaching the receiver. This process actuates the system by sending a signal through predefined ports and triggering the start of the timer (i.e., the crossing of sensor A starts the timer). The timer keeps incrementing after every second until another signal is received through another predefined port, which signals the end of the timing sequence (this happens when sensor B is crossed by the roller). Note that the time is captured and stored by the system controller, for use in necessary computations. The system controller then uses the stored values of distance and time to compute and store, the velocity and acceleration of the roller. The user makes a choice regarding the output result desired. It could be either the display of time taken to cover the selected distance, the velocity or acceleration of the roller. Once this is done, the reset button is pushed to clear the display for a new experiment.

4.0 Results

Here we present the results obtained after careful testing of the implemented apparatus for teaching dynamics. The results shown in Table 1 reveal the precision level of the device when compared to theoretical values. The experiment was conducted by setting the roller in motion along the rail between the sensors. Readings were taken for different rail lengths and timers were used to make comparative measurements with the digital values obtained by the device. The results show a close relationship in approximation between our device's measurement and theoretical values. The considerable level of precision of this device guaranteed from experimental results makes it a reliable tool in enhancing teaching of simple concepts in dynamics in secondary schools.

Table 1: Readings taken from the Device

Distance (cm)	20	40	60	80	100
Time (s)	1	1	2	2	3
Velocity (cms^{-1}) (approx.)	20	40	30	40	30
Acceleration (cms^{-2}) (approx.)	20	40	15	20	10

5.0 Conclusion

Employing effective and productive teaching methods will go a long way in improving the standard of education in Nigerian secondary schools. This necessitated the design and implementation of the Dynamics Teaching Apparatus presented in this paper. A brief literature review of some teaching techniques was presented to show the need to incorporate simple experimental structures as teaching aids alongside these techniques to improve quality of teaching. The technical design structure of the device was presented and the test results were shown. This design presents certain advantages that ensure ease of adaptability to the Nigerian local schools. These advantages are: it does not require rigorous training for teachers to be able to use it; it can be easily mass produced for local use at highly reduced cost, and does not depend only on public electric power supply for its function. Finally, its level of precision makes it rather reliable to be used in learning environments. This device has limitations in terms of calibrations. The time and distance calibrations are somewhat coarse. The authors however think that this is not adverse considering the level at which the apparatus will be used. The aim will still be achieved.

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