

Pedagogical Aspects Related to Sensors and Physics Experiments Coupled Computers

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ABSTRACT

The more accurate experiments on the centripetal force, the thermoelectric effect and the three-phase asynchronous motor are very necessary to increase the creativity and exploration of the high school students. Thus, we successfully designed the experiments coupled computers and then organized the pedagogically experimental classes to evaluate the effectivity of the designed experiments through the high school students' activities. We successfully designed the USB interface with a USB port, 5 ADC channels connecting to the sensors and 1 channel measuring the motor's speed. The teaching interface written by LabVIEW program is easy to use. The teachers can use a personal computer to couple the experiments and show the results in the large screen via a projector. These experiments coupled computers have the low cost from 100 – 200 USD and the error less than 5 %. The pedagogical results show that designed equipments can meet the standard of the performing experiments.

Keywords: *Experiments coupled computers, sensors, USB interface, physics teaching.*

1. INTRODUCTION

At present, there are many companies have manufactured the good equipments coupled computers applied to the industry and education. The famous interfaces as Cassy, Cobra, Science Workshop 750 are applied to the General Physics experiment in the universities. They have very high cost, which is not suitable for High School. Furthermore, at the Vietnamese universities, many authors have studied and fabricated the experiments coupled computers in physics teaching. However, the quantity is not enough for teachers' performing experiments.

When teaching the knowledge which relates to the centripetal force in the grade 10 physics curriculum, teachers get many difficulties because this force is the combination of the forces affecting the circular motion of the objects (Nguyen, et al., 2007). As a result, the students are notified of the formula to memorize it. This will have an effect on the development of thinking and the solid belief in physics knowledge of the students. Although in some universities, the centripetal force experiments have been built, when the objects rotate fast, it is difficult for the experimenters to read not only the cycle but also the force on the dynamometer. In addition, the experiments of the thermoelectric effect in grade 11 physics (Nguyen, et al., 2012) only allow the students to study the physics phenomenon qualitatively. Hence, teachers can not establish the ratio between the thermoelectric voltage and the temperature difference of the two ends of the thermocouple but they inform the ratio instead. Moreover, the dependence of the metal's resistivity on the temperature is presented in a simple way which is just the notification. Therefore, the excitement of exploring this knowledge of the learners is not encouraged. Furthermore, in grade 12 physics, the AC generators and three-phase asynchronous motors are highly practical applications (Luong, et. al., 2012). However, the teachers often report the rotating magnetic field of stator windings and the relationship between the phase voltage and the wire voltage. Consequently, the fabrication of the experiments coupled computers is to overcome these restrictions.

2. DESIGNING THE EXPERIMENTS COUPLED COMPUTERS

2.1. The USB interface and teaching software

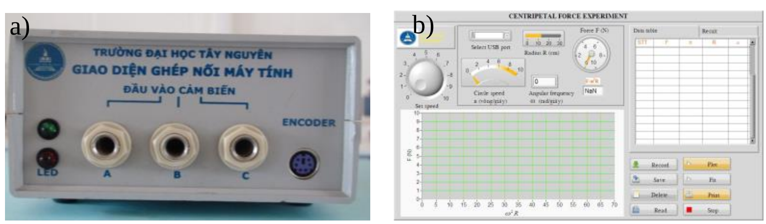

Figure 1. The USB interface (a) and teaching software (b).

The USB (Universal Serial Bus) interface is designed by using the PIC 18F4550 microcontroller with five channels to measure the voltages and one channel to measure the motor's speed. The use of the PIC microcontroller has the advantages (Microchip Technology Inc, 2003) which are stable work, USB 2.0 support, and plugging directly into a computer. The circuit board is placed in a plastic box (Fig. 1a). The data collection interface written by LabVIEW is easy to use (Fig. 1b). This software is designed to assist the teachers in storing and analyzing the data, plotting and fitting the graphs. Teachers can use the personal computer to connect to the experiments to perform the results in the large screen via a projector.

2.2. The survey experiment of the dependence of the metals' resistivity on the temperature

We used the water vessel made of transparent mica and installed the heating wire (5) to heat the Platin bar (Pt100) (1) (Fig. 2a), and set up a fan (2) controlled by the switch (3) is to increase the thermal convection. The water temperature is measured by the LM35 temperature sensor (4). The fabricated resistance sensor has the sensitivity of 52 mV/Ω, linear error of 1.3 % of the full scale, and the output

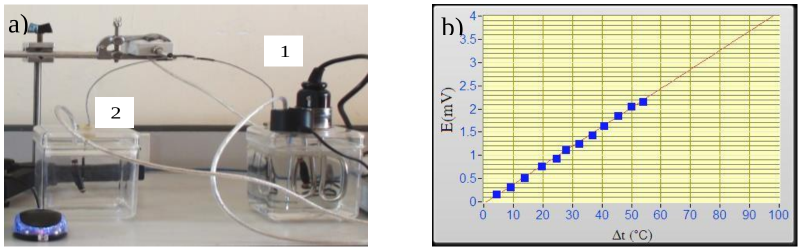

Figure 3. The experiment of the thermoelectric effect and the plot of thermoelectric voltage versus the temperature difference.

voltage range of 0.4 - 2.4 V.

We heated the water from 25°C to 50°C and recorded the resistance. From the experimental data, we find that the relationship between resistance R and temperature t is expressed by the function R = 100.46(1 + 0.00388.t). We find that the temperature coefficient of resistivity α of Platin is $3.88.10^{-3}$ K^{-1}. Comparing with the results of datasheet of the Pt100 ($3.90.10^{-3}$ K^{-1}) (Thermocouple Instruments Ltd, 1999), this experiment has a relative error of 0.5 %. Fig. 2b shows the plot of the resistance of the metal versus temperature is linear. Since R = ρl/S, where l is the length of the metal bar (in m), S is the cross section of the bar (in m^2), and ρ is the resistivity of metal (in Ω.m), thus if these quantities are assumed to be constant then $\rho = \rho_0(1 + \alpha.t)$.

2.3. The survey experiment of the thermoelectric effect

The thermocouple is made of Chromel - Alumel pair. One end (1) of the thermocouple is submerged into a plastic bottle which has the heating wire to heat water, and a fan to stir the water. Another (2) is kept in the other plastic bottle containing the mixture ice and water in order to keep at 0 °C (Fig. 3a). The temperature of the water is measured by the LM35 temperature sensors. The thermoelectric voltage is very small hence it is necessary to design an amplifier circuit to amplify its values. The temperature of the end (1) is raised from 0 °C to 55 °C and then the data can be recorded. Fig. 3b shows that the thermoelectric voltage E is proportional to the temperature difference Δt. After using the least

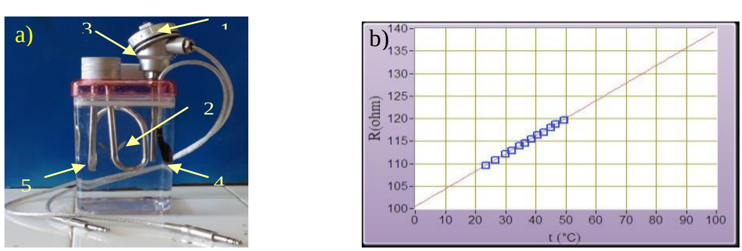

Figure 2. The survey experiment of temperature dependence of metal resistivity (a) and the plot of the resistance of the metal versus temperature (b).

square fit, we find that thermocouple coefficient is 41.3 μV/K. If comparing with the thermocouple coefficient of the type K thermocouple (41 μV/K) (Pyromation Inc**,** 2013), we obtained the relative error of 0.73%. Thus, this experiment can be used to examine the thermoelectricity effectively.

2.4. Centripetal force experiment

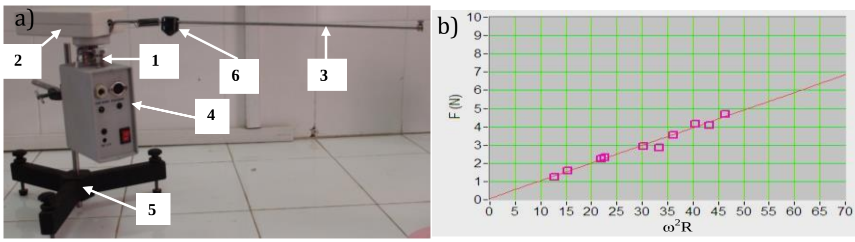

Figure 4. The centripetal force experiment and the plot of the relationship between the centripetal force and ω^2R.

Fig. 4a shows the rotating system. The brush system (1) is designed to obtain the signal from the force sensor (2). Each pair of brushes made of thin aluminum bar is rested on two coaxial copper rings mounted on the rotation axis of the motor. This axis transmits the motion for the inox bar (3). A motor integrated the encoder is installed in a plastic box (4) and is mounted on the experimental support (5). The motor speed is adjusted by the speed controller. The 100 g mass (6) is coupled on the end of the spring which is connected to the hook on the force sensor. This object can slide freely on the bar which has the length of 35 cm. The force sensor is designed by placing four tenzo-resistors on an aluminum substrate to form the bridge circuit. The sensor has the high sensitivity of 0.52 V/N, linear error of 0.2% of the full scale and the output voltage range of 0 – 5 V.

When the motor speed n is changed, the angular velocity ($\omega = 2\pi n$), the radius of curvature R and the centripetal force F are changed as well. After fitting the graph, we find that the ratio $F/m\omega^2R$ is 0.96. This ratio is the mass of the object (96 g) and the relative error is 4 %. Viewing the points of the experimental data (squares) and the fitted line (solid line), we can conclude that $F \sim \omega^2R$ (Fig. 4b). Thus, this experiment can be used to illustrate the centripetal force equation and introduce a method for learners about the measuring the mass of the objects.

2.5. Three-phase asynchronous motor experiment

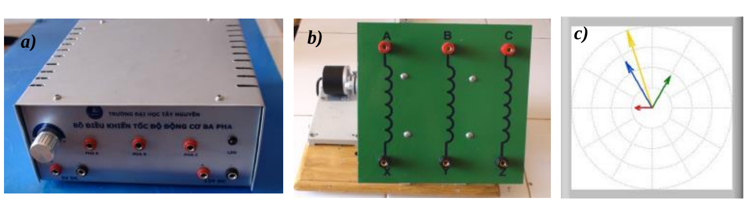

Figure 5. Speed controller (a), panel for wiring and encoder for recording the speed of motor (b), and rotating magnetic field (c).

The three-phase asynchronous motor experiment consists of two major parts: the speed controller (Fig. 5a) and three-phase asynchronous motor (Fig. 5b).

The speed controller is designed to convert one-phase voltage 220 VAC to three-phase 18 VAC and can change the voltage which applies to the stator windings. The panel for the star and delta connection and encoder with 100 pulses per circle to record the motor speed are mounted on a wooden base. The voltage sensor is fabricated with the linear error of 1.63 % of the full scale and the output voltage range of 0 – 5 V. The teaching interface can show the rotating magnetic field of the stator windings via the longest vector (Fig. 5c). The average ratio U_d/U_p is 1.74 (Table 1) compared to the theorical ratio ($\sqrt{3} = 1.73$), we get a relative error of 0.58 %.

Table 1. The ratio of wire voltage U_d and phase voltage U_p

Number	U_p (V)	U_d (V)	U_d/U_p
1	10	17.17	1.72
2	9.95	17.35	1.74
3	9.88	17.18	1.74
4	9.84	17.45	1.77
5	9.74	17.47	1.79
6	9.93	16.98	1.71
7	9.9	17.23	1.74
8	9.99	17.23	1.72
9	9.73	17.08	1.76
10	9.84	17.26	1.75

3. RESULTS OF PEDAGOGICAL EXPERIMENT

The experimental pedagogy was conducted in 6 classes at Cao Nguyen Practical High School of Tay Nguyen University (2 classes of grade 10 with 90 students, 2 classes of grade 11 with 92 students, 2 classes of grade 12 with 91 students) during the period from October, 2012 to December, 2012. We organized to teach with the prepared teaching process using the fabricated experiments coupled computers. According to the recorded information, we primitively evaluate the quality and effectiveness of the fabricated experimental devices and of the teaching process in promoting the positivity and creativity of the learners. The technical and pedagogical nature of the fabricated equipments was evaluated the criteria: results of the experiment (1), aesthetician (2), method and conducting period (3), and the software interface (4). In Fig. 6, the experiments of the temperature dependence of metal resistivity, thermoelectric effect, centripetal force and three-phase synchronous motor are labeled I, II, III, and IV, respectively. The percentage of levels from A to D, which were chosen by students, is shown on the left hand scale of Fig.6.

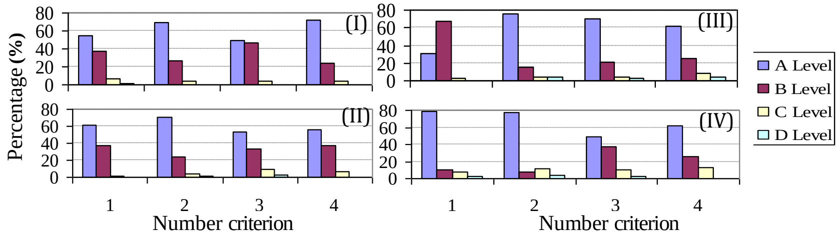

Figure 6. Analysis of the survey results of the experiments' qualities.

With respect to the results of the experiment, most of the experiments are appreciated at A level (clear and accurate) and B level (relatively accurate) in the range of 55 - 77.8 % and 20 – 37.5 %, respectively. The level for C (incorrect) and D (another idea) is very low in the range of 6.3 - 8.1 %. However, the centripetal force experiment III has B level with high rate of 67.4 %, which indicates that the brushes cause large errors. With respect to the aesthetician, the results show that A and B levels (very nice and nice) have the high percentage (85 %). As regards the method and conducting period, the ratio of A level (simple and time-saving) has the highest percentage of 49 % - 70.6 %, and level B (simple and time-consuming) is from 21.2 - 46.4 %, and the C (complex and time-consuming) and D (another idea) levels are from 3.6 - 13.1 %. The percentage of B levels for the experiments I and IV is high. This is one of the most difficult criteria for the performing experiments because the teachers have to experiment complicatedly and need many times. With respect to the software interface, A and B levels were chosen (good, scientific) with the high percentage (87.1 % - 95.8 %). This is a major strength of the experiments coupled computers.

During the teaching process, we also found that learners concentrated on listening to their teachers and actively expressed their opinions. They not only positively discussed in their groups (Fig 7a), but also they focused on solving the individual learning tasks as well (Fig 7b). They often asked for more time to solve teacher's request.

Figure 7. Learners expressing their opinions and discussing in their groups.

Thus, the experiments coupled computers are feasible for the process of teaching physics in High Schools. Using these experiments, teachers can survey the deeper relationships between the physical quantities while the current experiments get the problem. However, teachers should install the parts of the experiments I and IV before teaching to save time. Furthermore, using the new designed experiment and the introductory and solvable teaching method, we can create the positive activities and creativity of the learners.

4. CONCLUSION

We successfully fabricated experiments coupled computers which include the experiments of the temperature dependence of metal resistivity, thermoelectric effect, centripetal force and three-phase synchronous motor. They have low cost from 100 – 200 USD and the relative error is less than 5 %. The pedagogical results show that fabricated equipments can meet the standard of the performing experiments and they can support the teachers to create the excitement and exploration for the learners. These experiments should be improved the accuracy and created the feasibility for application in physics teaching.

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