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Research Paper

Determination The Coefficient of Restitution in Object as Temperature Function in Partially Elastic Collision Using Phyphox Application on Smartphone

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Abstract

This research aims to determine the coefficient of restitution in object experiencing partially elastic collision when the object falls free using the phyphox application on smartphone. In terms of experiment, this experiment was carried out five times with different temperature. The smartphone is connected on PC through the same wifi network or using tethering by entering the search address that available on phyphox application. After that, the smartphone placed on the board that used as a base when the object dropped, then the object released from the certain height. Data collecting process started by running the phyphox application through a PC to collect the measurement data. The data collected on smartphone is exported to Ms. Excel to fit the data and then the results are plotted in graphical form. The result of the analysis shows the coefficient of restitution value of the object that had variations based on experiment with each temperatures at 32 °C, 28 °C, 24 °C, 20 °C 18 °C and the coefficient of restitution values are 0.889 ± 0.006, 0.890 ± 0.008, 0.891 ± 0.003, 0.892 ± 0.003 and 0.893 ± 0.003. The result of research shows that the lower of the temperature so theres increasing on the coefficient of restitution. So that the coefficient of restitution has avarage's value is 0.891 ± 0.002.

Keywords

coefficient of restitution ,smartphone, phyphox application

1. INTRODUCTION

The elastic of ball in a table tennis game is catagorized in partially elastic collision, where the object hit to the table occurs of contact that will be caused lose the energy. (Ahmad et al., 2016). The coefficient of restitution (e) is parameter used to determine the loss of energy in the object during collision by measuring how much the ball bounces (Jang and Kim, 2014). The coefficient of restitution can be influenced by the temperature in the playing room so it can reduce of the performance of the table tennis athletes and it affects on the match results (Chang, 2016). The previous research has found relation between temperature and the coefficient of restitution, that is an increase of temperature can affect the decrease of the coefficient of restitution at many balls where the material stiffness decreases because of increases the temperature (Wiart et al., 2011)). The results of the coefficient of restitution of table tennis ball at the differents temperature with using the motion sensor produce a significant number that is 0.821-(0.0003) (Chang, 2016), while the other research with using digital oscilloscope to measure the coefficient of restitution of table tennis ball with plastic ball had an avarage of the coefficient

of restitution of 0.80 (Wadhwa, 2009). ITTF (International Table Tennis Federation) explain that any surface from any material will produce the uniform reflection about 24.0 cm when the standard ball is dropped from the height of 30.5 cm (de la Roche, 2017). Then, the resulting coefficient of restitution is e = 0.887.

Partially elastic collision occur when the ball hits the hard surface and some of the kinetic energy was losing when the ball changes the shape in its contact with the hard surface (Jawet, 2009). Partially elastic collision only acceptable with the law of conservation of momentum and the coefficient of restitution in partially elastic collision has a value between 0 and 1 (0 < e < 1) (Mughny and Rahmawati, 2016). Partially elastic collision as shown in Figure 1.

In Fig. 1 if the ball is released from a certain of height, it will fall and hit the floor repeatedly. The collision is usually followed by the appearance of heat on the surface of two objects that makes contact. That heat comes from the kinetic energy of objects when the collision occur (Giancoli, 2014). The kinetic energy that occurs will decrease when the objects (the ball of table tennis) comes into contact with the floor, it will decrease,
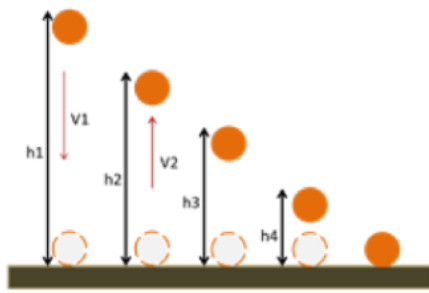
Figure 1. The ball is dropped

it caused by friction between the ball and the floor (Abdullah, 2017). Generally, stress in waves appears during the collision which caused energy lose and the coefficient of restitution will decrease (Ye et al., 2019; Wu et al., 2005).

2. EXPERIMENTAL SECTION

2.1 The tools and materials

The tools and materials used in this study are: smartphone as a sensor that will install of the phyphox application and it will catch the sounds when the ball hits the floor, PC as a remote to make it easier to conduct of research and read the data that has been recorded by smartphone and the PC makes easier to analyze data, table tennis ball is an object that will be dropped from a certain height, and measure the temperature of the room first then conduct research using a thermometer.

2.2 Methods

The research method includes experimental procedures started from:

2.2.1 Research Preparation Phase

The preparatory phase includes installing the phyphox application on the smartphone, activating remote access on the smartphone connect to PC and smartphone through the same wifi network or connecting with tethering. The phyphox application provides a private IP address that can be entered into the PC browser where the remote access can connected with mobile device. Then, measuring the temperature in the room, to find out what is the temperature before the experiment. After that, the research was carried out with the object dropped from a certain height on the floor. After hits the floor of the ball was bouncing and makes the sound. The sound generated from the collision was recorded by a smartphone and the data will be recorded on a PC, then it will be exported in the form of Microsoft Excel and the data can be analyzed. The experiments will be carried out in the same method at different temperatures. The data as shown in Figure 2 and Figure 3.

Figure 2 and Figure 3 are the results of experiments recorded on the PC when taking data at 28 °C, where the results obtained are the energy, time and the height.
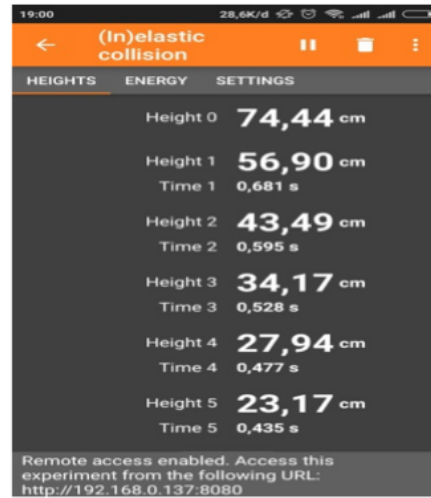

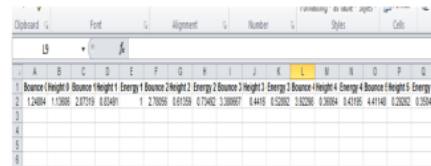**Figure 2.** Experimental results data for the temperature of 28 °C

Figure 3. Export data to Excel for a temperature of 28 °C

2.2.2 Collecting the Data

The scheme of the tools used when data collection is shown in Figure 4.

Figure 4. Schematic of experimental device

2.2.3 Analysis Microsoft Excel

Data obtained from the research then exported in the form of MC excel is value of Δt different times, height h_1, h_2, ... , hn and the energy. Based on some known the data , we can find the value of the coefficient of restitution and energy ratio by creating a new column in Excel. The coefficient of restitution of the table tennis ball can be calculated by the equation (Roux and Dickerson, 2007).

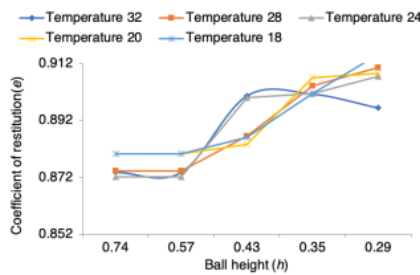$$e = \sqrt{\frac{h_2}{h_1}} \tag{1}$$

Figure 5. Relationship between the coefficient of restitution and the height of each temperature

Figure 6. Relations between the average of the coefficient of restitution the table tennis ball on temperature

The energy ratio is calculated by using the following equation (Wu et al., 2005).

$$\lambda = 1 - e^2 \tag{2}$$

2.2.4 Analysis Data Methods

The method is using weighted least square by finding the average value of the coefficient of restitution as a function of temperature with equations (1) and (2), then from the results of the analysis of the data are plotted on the graph so that it will be seen whether there are significant differences in the coefficient of restitution of the object due to the influence of temperature.

3. RESULTS AND DISCUSSION

Experiments have been carried out to determine the coefficient of restitution of objects as a function of temperature in the partially collision collision using a phyphox smartphone application. The result of the coefficient of restitution have been obtained at different temperatures. The data obtained from the experimental results for various of the temperatures are shown as in Table 1.

The results of data collecting, as presented in table 1 was carried out as many as 5 experiments at different temperatures 32 °C, 28 °C, 24 °C, 20 °C and 18 °C. The coefficient of restitution in objects for each temperature was recorded on the phyphox application by data from 6 data of the height of the reflection on the table tennis ball. Based on theory, the coefficient of restitution of objects is obtained from the results of a comparison between the root of height after the objects bounce and the root of height before the objects bounce.

Based on the results of the coefficient of restitution obtained from the results of the experiment, then the results plotted in the form of the graph at each temperature is shown Figure 5.

Figure 5 shows the coefficient of restitution value of table tennis ball based on the height of the reflection of the ball when it hits the floor based on the results of recorded on the phyphox application. The results of the coefficient of restitution obtained from this experiment have an irregular deviation, while the expected restitution coefficient must be constant. The data obtained is less than the maximum because of each of ball has stitches. It is because of the falling ball does not hit the surface which is always the same on the ball so that occasionally it hits
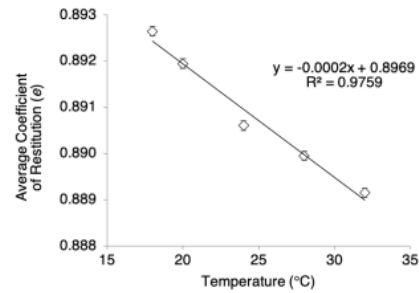
on a hard surface on the ball (ball stitches). This was mentioned (Gonzalez et al., 2017) in this research that the coefficient of restitution of objects for collisions is dependent on the character of the two objects colliding, the ball and the horizontal surface of the floor. This causes of the coefficient of restitution obtained is not in a constant state.

The results of these experiments then obtained the graph of the value of the coefficient of restitution that has been averaged at each different temperatures and obtained different results, where the coefficient of restitution of object (table tennis balls) will decrease if the temperature increases as shown in Figure 6.

In Figure 6 shows that there is effect of temperature on the coefficient of restitution of objects (table tennis balls). The graph in Figure 6 shows that the more increasing the temperature, the coefficient of restitution of objects (table tennis balls) will be decreased. The coefficient of restitution obtained is 0.889 ± 0.006, 0.890 ± 0.008, 0.891 ± 0.003, 0.892 ± 0.003 and 0.893 ± 0.003. The results obtained are in suitable with the coefficient of restitution the object in theory. The theory explains that the partially elastic collision occurs so that the coefficient of restitution value revolved between more than zero and less than one (0 < e > 1) (Ahmad et al., 2016; Fairbrother et al., 2006). The results of average of the coefficient of restitution value of table tennis ball that obtained from the experiment is 0.891 ± 0.002.

The results of studies from some journals that use different methods explain that the the coefficient of restitution of object (table tennis balls) decreases at high temperatures (Gonzalez et al., 2017; Chang, 2016), but this experiment does not effective to other objects or balls, for example tennis balls, billiard balls, and soccer balls or the balls that had thicker material, because the graph is inversely proportional to the table tennis balls Tamiya (2010); Wadhwa (2013); Gonzalez et al. (2017). According to the International Table Tennis Federation (FTMI), good value of the coefficient of restitution of table tennis ball is so can determined based on the experimental results is good value of the coefficient of restitution on a table tennis ball at 32 °C.

Decreasing the coefficient of restitution of table tennis ball because of the energy released each time of the collision. The experimental show on data in Table 1, it can be calculated how much kinetic energy is lost at each temperature with equation

Table 1. The result of analysis data of the coefficient of restitution at each temperature

Height (h)	The coefficient of restitution (e)	T (°C)	The average of The coefficient of restitution (e)
0.74	0.874	32	0.889 ± 0.006
0.57	0.874		
0.43	0.901		
0.35	0.901		
0.29	0.896		
0.23			
0.74	0.874	28	0.890 ± 0.008
0.57	0.874		
0.43	0.886		
0.34	0.904		
0.28	0.911		
0.23			
0.75	0.872	24	0.891 ± 0.003
0.57	0.872		
0.44	0.9		
0.35	0.901		
0.29	0.907		
0.24			
0.71	0.88	20	0.892 ± 0.003
0.55	0.88		
0.43	0.884		
0.34	0.907		
0.28	0.909		
0.23			
0.74	0.88	18	0.893 ± 0.003
0.57	0.88		
0.44	0.886		
0.35	0.901		
0.28	0.915		
0.24			

(2) so the results can be shown in Table 2

Table 2. The ratio of the kinetic energy lost at each different temperature

Temperature (°C)	e	e^2	λ
32	0.889	0.791	0.209
28	0.89	0.792	0.208
24	0.891	0.793	0.207
20	0.892	0.796	0.204
18	0.893	0.797	0.203

Figure 7. Relation between the lost energy and the mean square root of the coefficient of restitution as a function of temperature

In Table 2 shows that there is the energy lost in each collision of objects, this can be seen in the presentation of the calculation results λ. There is the difference that shows the more increasing the release of energy at the increase temperatures. This is shown at Figure 7.
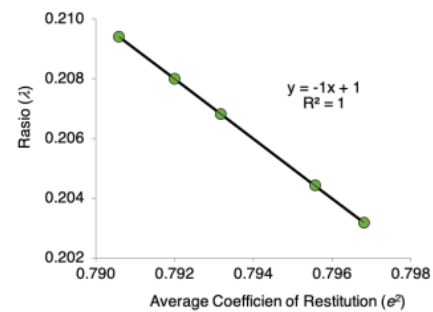
Figure 7 shows the relation between the lost energy and

the coefficient of restitution, where the object will be wasted more energy at small the coefficient of restitution. Based on the research. explains that decreasing of the coefficient of restitution that there is only slight decrease in kinetic energy as caused of bounce. The coefficient of restitution of object decreases at high temperatures at 32 °C as shown in Figure 8.
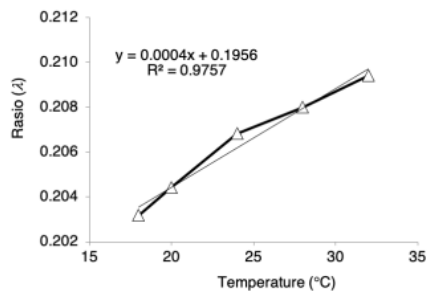

Figure 8. Relation between the lost energy and the temperature

The coefficient of restitution decreases and it is contrary to the kinetic level of energy loss which increases significantly. This is because of the object material stiffness will be soften at high temperatures. The heat treatment has the aim of increasing ductility, eliminating internal stress, smoothing the size of crystal grains and increasing the hardness or tensile strength of metals. So, it can be concluded that the more objects do collisions , the lost energy lost will be more too. The effect of temperature is increasing the amount of energy lost each time of collision. Collisions always accompanied by the lost energy , which determine the magnitude of the coefficient of restitution that ranging from 0 to 1.

4. CONCLUSIONS

Based on the discussion that has been explained, the phyphox application on a smartphone can be used in physics experiment and scientific demonstration in the classroom and can be used at home, so it is very helpful without the need to pay expensive when did the practicum. This research can also support more time compared to previous research, because of the data that shown in the phyphox application is very complete, so it can be directly processed in Microsoft Excel. Using the phyphox application in measuring the coefficient of restitution of object as temperature function more effectively applied in learning.

The results of the research have obtained of relation between the coefficient of restitution with room temperature. The higher of the room temperature, the coefficient of restitution of the object (table tennis ball) is getting smaller. This can be showed in the graph how the coefficient of restitution of objects increases as the low of temperature in the room. The average the coefficient of restitution that obtained is 0.891 ± 0.002. The results is more accurate than the small standard deviation value (0.002) while the coefficient of restitution is quite accurate with regard to the coefficient provided by ITTF (International Table Tennis Federation) with error at 0.5% and the previous research had error at 7%.

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