One dimensional two-body collisions experiment based on LabVIEW interface with Arduino

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Abstract. The purpose of this work is to build a physics lab apparatus that is modern, low-cost and simple. In one dimensional two-body collisions experiment, we used the Arduino UNO R3 as a data acquisition system which was controlled by LabVIEW program. The photogate sensors were designed using LED and LDR to measure position as a function of the time. Aluminium frame houseware and blower were used for the air track system. In both totally inelastic and elastic collision experiments, the results of momentum and energy conservation are in good agreement with the theoretical calculations.

1. Introduction

Previous, important contributions to classical physics were provided by Newton, who was also one of the originators of calculus as a mathematical tool. But current, studying classical mechanics was demonstrated by experiment in the laboratory for research and teaching. This portion of classical mechanics is called kinematics [6]. From ordinary experience, we know that motion of an object represents a continuous change in the object of position, velocity, speed and acceleration. So, the instrument of a glider of length moves through a stationary photogate on an air track (GMSP) [1] was developed for studying about relation of position, velocity, speed, acceleration and time in the motion. This instrument was taught in the physics laboratory at university. However, GMSP was still difficult to understand because it lacks the information management analog system of the experiment. The GMSP was expensive, scarce and unsuitable for teaching many students.

Recently, Arduino Uno [2] and the LabVIEW [3] program have been widely used and interestingly applied in various fields. They are used with much simple physics experiment such as light measuring and analyzing. They will make more efficient physics experiments, easier data mensuration and display, and more interesting physics teaching for students. They are so interesting for the development of the GMSP system to be more effective.

In this work, we were success to fabricate the GMSP which was devolved with Arduino Uno and LabVIEW system. It was called the GMSP. It was made from the local around material by DIY (Do it yourself) process. The momentum and kinetic energy of this system was studied about the perfectly inelastic collisions and the elastic collisions by the GMSP. The GMSP can control, display for user friendly, low cost and able to teach laboratory for many students.

2. Experimental

The GMSP was made from the local around material by DIY (Do it yourself) process. It was composed of a glider, photogate sensor set and air track shown in the Figure 1. A glider set consists of flag and glider was shown in the Figure 1(c). The glider is made from aluminum L bar which has 2 mm-thickness and 120 mm-length. The flag is a plastic with the width and length of 30 and 100 mm, respectively. It has attached to the glider. In Figure 1(b), the air track is an aluminum frame houseware which has 2 mm-thickness and 2000 mm-length. One end is closed and another one end is designed for air flow from blower with a diameter of 30 mm. It has drilled on both side with a diameter of 0.8 mm. A glider was putted on the air track, the air flow from blower is spray out of the tiny hole underneath it, so it floated and there was none friction between their surface. The Photogate sensor [5] set was composed of a light-emitting diode (LED) which was a light sources and phototransistor (LDR) which was a light sensor. The electronic circuit of photogate consists of resistor R_1 and R_2 was 100 Ω and The Arduino board supplies the voltage (V_{cc}) was 5.0 V. The photogate output (V_{out}) was connected to the analog input pin A_0 - A_5 of the Arduino board. Then, the GMSP was connected to Arduino Uno microcontroller board which was interfaces between GMSP and program controller. To communicate between the photogate and an Arduino Uno microcontroller board, the LabVIEW is used to interface through the MakerHub LINX add-on [4]. Finally, the conservative of momentum and kinetic energy of the system was experimented about the perfectly inelastic collisions and the elastic collisions by the GMSP is show in Figure 2.

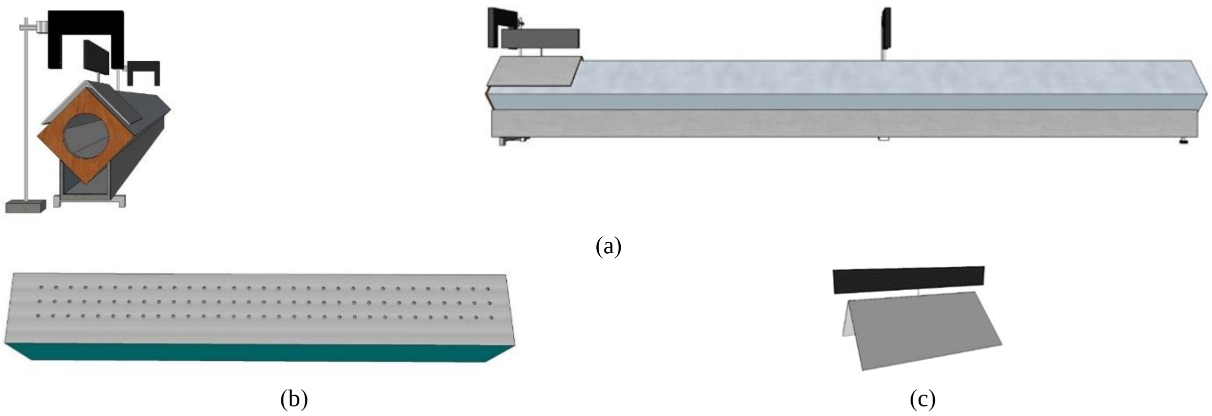

Figure 1. (a) The low-cost air track was invented by the DIY process from the aluminium frame houseware (b) the air track is made from an aluminium frame houseware (c) a glider set consists of flag and glider.

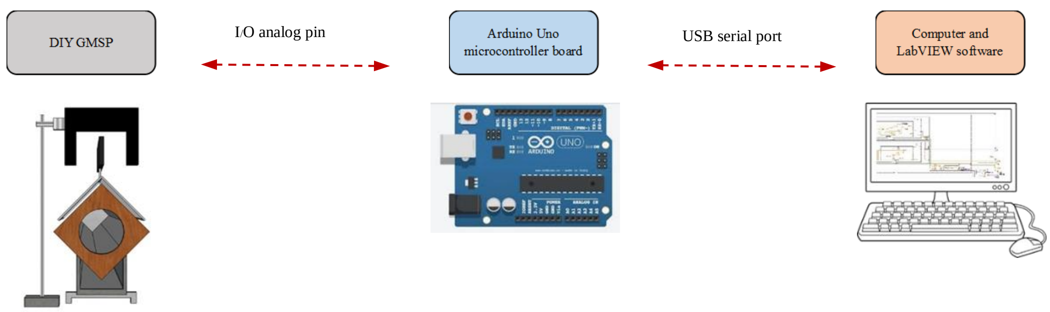

Figure 2. The GMSP is connected I/O analog pin Arduino boards interface with computer LabVIEW program.

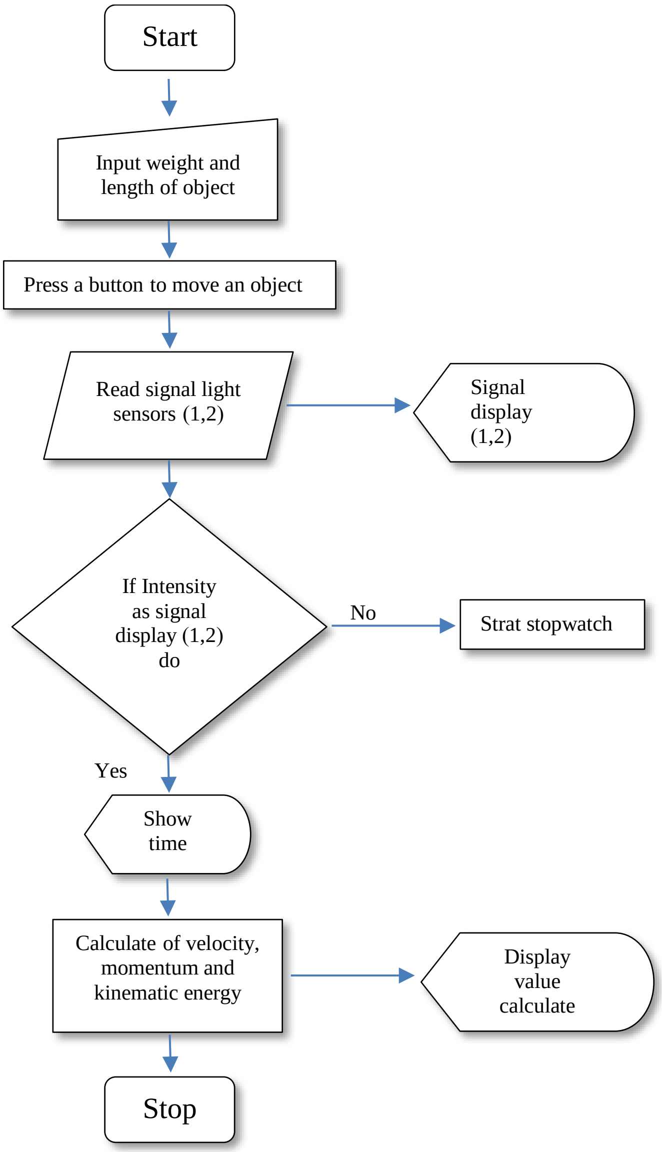

Figure 3. The elastic collision and the perfectly inelastic collision programming flowchart.

LabVIEW is used as a design platform for the system. The flow of the experiment is illustrated in flowchart in Figure 3. The concept of the collisions in one dimension described in this experiment is the perfectly inelastic collisions and elastic collisions [6].

An inelastic collision is one in which the total kinetic energy of the system is not the same before and after the collision (even though the momentum of the system is conserved). Inelastic collisions are of two types. When the objects stick together after they collide, as happens when a meteorite collides with the Earth, the collision is called perfectly inelastic. When the colliding objects do not stick together but some kinetic energy is transformed or transferred away, as in the case of a rubber ball colliding with a hard surface, the collision is called inelastic. When the rubber ball collides with the hard surface, some of the ball's kinetic energy is transformed when the ball is deformed while it is in contact with the surface. Inelastic collisions are described by the momentum version of the isolated system model. The system could be isolated for energy, with kinetic energy transformed to potential or internal energy. If the system is no isolated, there could be energy leaving the system by some means. In this latter case, there could also be some transformation of energy within the system. In either of these cases, the kinetic energy of the system changes.

Elastic Collisions: Consider two gliders of masses M_1 and M_2 moving with initial velocities $\vec{v}_{iM_1}$ and $\vec{v}_{iM_2}$ along the same straight line as shown in Figure 4 (a). The two gliders collide head-on and then leave the collision site with different velocities, $\vec{v}_{fM_1}$ and $\vec{v}_{fM_2}$. In an elastic collision, both the momentum and kinetic energy of the system are conserved. Therefore, considering velocities along the horizontal direction in Figure 4 (b). We have.

$$P_i = P_f$$

$$M_1\vec{v}_{iM_1} + M_2\vec{v}_{iM_2} = M_1\vec{v}_{fM_1} + M_2\vec{v}_{fM_2} \quad (1)$$

$$E_{Ki} = E_{Kf}$$

$$M_1\vec{v}_{iM_1}^2 + M_2\vec{v}_{iM_2}^2 = M_1\vec{v}_{fM_1}^2 + M_2\vec{v}_{fM_2}^2 \quad (2)$$

Perfectly Inelastic Collisions: Consider two gliders of masses M_1 and M_2 moving with initial velocities $\vec{v}_{iM_1}$ and $\vec{v}_{iM_2}$ along the same straight line as shown in Figure 4 (c). The two gliders collide head-on, stick together, and then move with some common velocity $\vec{v}_{f(M_1+M_2)}$ after the collision. Because the momentum of an isolated system is conserved in any collision, we can say that the total momentum before the collision equals the total momentum of the composite system after the collision.

$$M_1\vec{v}_{iM_1} + M_2\vec{v}_{iM_2} = (M_1 + M_2)\vec{v}_{f(M_1+M_2)} \quad (3)$$

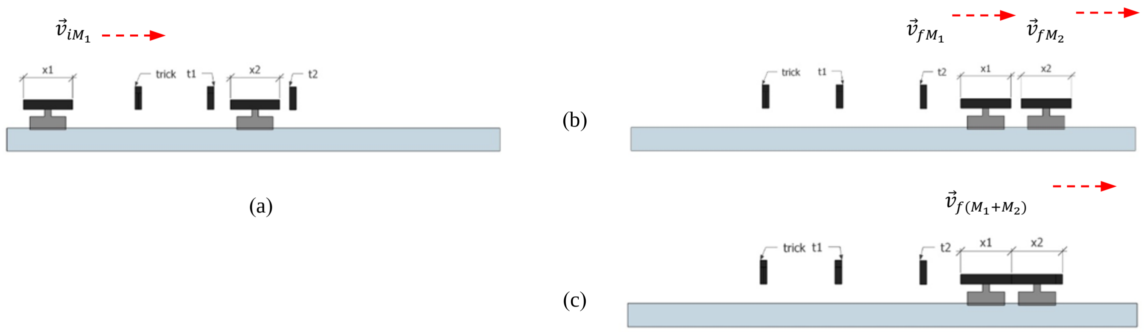

Figure 4. Schematic representation of an elastic collision between two gliders and a perfectly inelastic collision between two gliders (a) before the collision, the M_1 move (b) after the collision, the M_1 and M_2 move separately with new velocities on the track M_2 at rest (c) after the collision, the M_2 and M_2 move together with the same velocities.

3. Results and Discussion

3.1. Elastic Collisions

After the system was set up, shown in Figure 5. The glider M_1 is attached to solenoid coil, since the switch is pressed the spring force of the solenoid coil will be hit the glider M_1. When the first edge of the flag is cut the beam (1st photogate), the timer is already started while another edge of the flag is pass through the beam, the timer will be stop. We can get the velocity $\vec{v}_{iM_1}$ of the glider M_1 from the flag length and time interval between the flag pass through the photogate. The glider M_1 will be moved to collide the glider M_2 which is initially at rest. After the collision, the gliders M_1 and M_2 have moved separately with new velocities. The 2nd photogate will be measured the time interval of the gliders (M_1 and M_2), then we will get the velocities of M_1 and M_2 are $\vec{v}_{fM_1}$ and $\vec{v}_{fM_2}$, respectively. The experimental data was shown in the table 1.

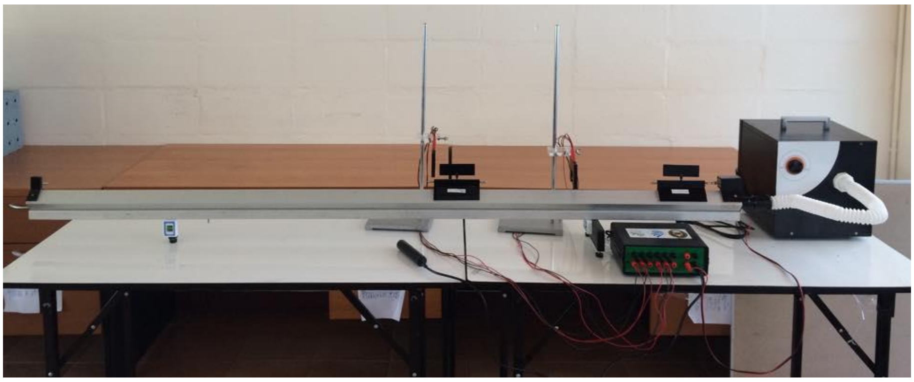

Figure 5. An apparatus of the GMSP set up.

Table 1. The elastic collision experimental data.

No.	v_i	v_f		P		E_K	
		M_1 (0.1432 g)	M_2 (0.1392 g)	P_i	P_f	E_{Ki}	E_{Kf}
1	0.3048	0.1865	0.1572	0.0436	0.0486	0.0133	0.0165
2	0.3303	0.1861	0.1702	0.0473	0.0503	0.0156	0.0177
3	0.3099	0.1778	0.1662	0.0443	0.0486	0.0137	0.0165
$\bar{x}$	0.3150	0.1834	0.1645	0.0451	0.0492	0.0142	0.0169
SD	0.01349	0.004912	0.006658	0.00197	0.000981	0.00123	0.000693

3.2. Perfectly Inelastic Collisions

Set up the system same as the elastic collision experiment but the small magnet will be attached at the end of the 2nd glider. Only the after collision will be differenced from the elastic collision experiment which is the gliders (M_1 and M_2) will be moved together with the same velocity. The experimental data was shown in the table 2.

Table 2. The perfectly inelastic collision experimental data.

No.	v_i	$v_{f(M_1+M_2)}$	P	
			P_i	P_f
1	0.3245	0.1718	0.0464	0.0495
2	0.3341	0.1793	0.0478	0.0517
3	0.3066	0.1653	0.0439	0.0477
$\bar{x}$	0.3217	0.1721	0.0460	0.0496
SD	0.01396	0.007006	0.00198	0.00200

4. Conclusions

The experimental result of an elastic collision shown that the apparatus of GMSP can be demonstrated the momentum and kinetic energy are conservative. The initial and final momentum and kinetic energy are 0.0451±0.00197 kg m/s, 0.0492±0.000981 kg m/s, 0.0142±0.00123 J and 0.0169±0.000693 J, respectively.

The experimental result of a perfectly inelastic collision shown that the apparatus of GMSP can be demonstrated the momentum is conservative. The initial and final momentum is 0.0460±0.00198 kg m/s, 0.0496±0.00200 kg m/s respectively.

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