HACETTEPE ÜNİVERSİTESİ
Fizik Mühendisliği Bölümü

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Experiment-5: Collision in Two Dimensions

Isaac Newton (1642 – 1727)**:** His father, a farmer, died three months before Newton was born.

At 12 he started King's School in Grantham and studied there until he was 17. In 1661 he entered Trinity College at the University of Cambridge. He received bachelor 's degree from this school in April 1665. When he started his graduate studies, his university was closed due to the plague epidemic. Taking refuge in his mother's farm for the purpose of epidemic protection, Newton made his most important discoveries during his two years there. After completing his postgraduate studies, Newton was appointed professor of mathematics at Cambridge University in 1669 at the age of 27. Newton's major contributions to science are in the field of mechanics. He formulated mechanical laws and basic concepts before the age of 30. Newton was the first to mathematically explain the relationship between force and momentum.

Göksoy Kort
21832009

Checked.

Supervisor:

Signature:

5.1. Objectives:

Our aim is to examine the principles of conservation of momentum and conservation of kinetic energy. Since the net force is zero in the experiment, the conservation of momentum principles is examined. Since external forces such as friction force are not taken into account in the experiment, the conservation of kinetic energy principles is examined.

5.3. Experiment:

Section I:

Experimental Procedure:

To determine the velocity of the incoming ball ($\vec{v}_1$) before the collision, first mark the starting point of the incoming ball (O). Then release the incoming ball while the target ball is not placed. Repeat this procedure 10 times from the same position.

Place the target ball on the vertical screw. Mark the starting points of both balls (GO and HO) to determine the velocity of the incoming ball ($\vec{u}_1$) and target ball ($\vec{u}_2$) after the collision.

Roll the incoming ball off the ramp without initial speed and have it collide with the target. Repeat this procedure 10 times from the same position.

The initial position of the target ball must not change during these collisions and the incoming ball must always be released from the same height.

To determine the velocity of the balls, draw vectors on the paper so that the predetermined starting points of each ball are the starting points and the points where the balls fall after the collisions are the end points.

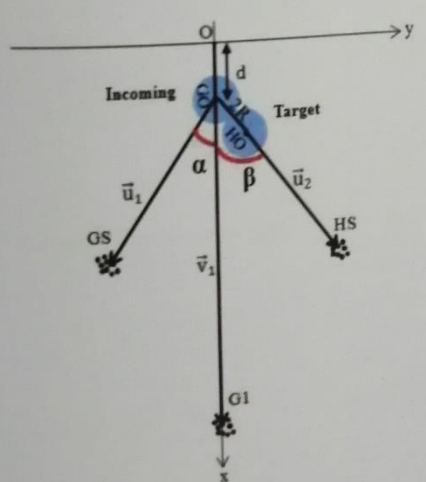

Figure 5.1

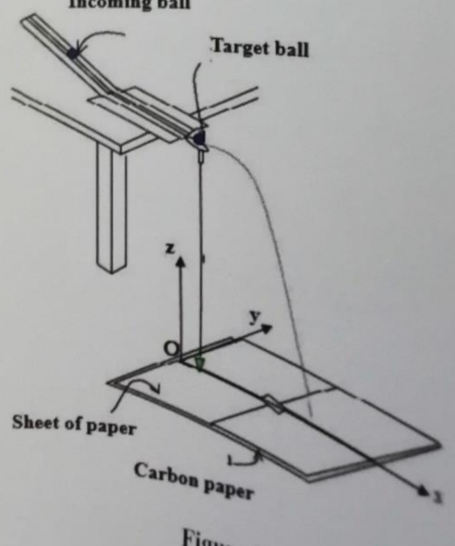

Figure 5.2

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Data Table:

$\|\vec{v}_1\|$ (cm)	$\|\vec{u}_1\|$ (cm)	$\|\vec{u}_2\|$ (cm)	α (°)	β (°)
36.5	21.7	26.2	49	39

Note: Draw the measurement results and copy the vectors on a sheet of paper from the the graph paper by scaling.

Calculations: $\boxed{m_1 = m_2 = 16\,g}$

Conservation P_x

$$m_1 \times v_1 = m_1 \times U_1 \times \cos\alpha + m_2 \times U_2 \times \cos\beta$$

$$16g \times 36.5\,cm/s \cong 16g \times 21.7\,cm/s \times \cos(49) + 16g \times 26.2\,cm/s \times \cos(39)$$

$$584\,g\,cm/s \cong 227.8\,g\,cm/s + 325.8\,g.cm/s$$

$$584\,g\,cm/s \cong 553,6\,g.cm/s$$

Conservation P_y

$$0 = m_1 \times U_1 \times \sin\alpha - m_2 \times U_2 \times \sin\beta$$

$$0 \cong 16g \times 21.7\,cm/s \times \sin(49) - 16g \times 26.2\,cm/s \times \sin(39)$$

$$0 \cong 262,1\,g\,cm/s - 263.8\,g\,cm/s$$

$$0 \cong 1.7\,g\,cm/s$$

Conservation KE

$$\frac{1}{2} m_1 . v_1^2 = \frac{1}{2} m_1 . U_1^2 + \frac{1}{2} m_2 . U_2^2$$

$$\frac{1}{2} \times 16g \times (36.5\,cm/s)^2 \cong \frac{1}{2} \times 16g \times (21.7\,cm/s)^2 + \frac{1}{2} \times 16g \times (26,2\,cm/s)^2$$

$$10658\,g\,cm^2/s^2 \cong 3767.1\,g\,cm^2/s^2 + 5491,5\,g\,cm^2/s^2$$

$$10658\,g\,cm^2/s^2 \cong 9258.6\,g\,cm^2/s^2$$

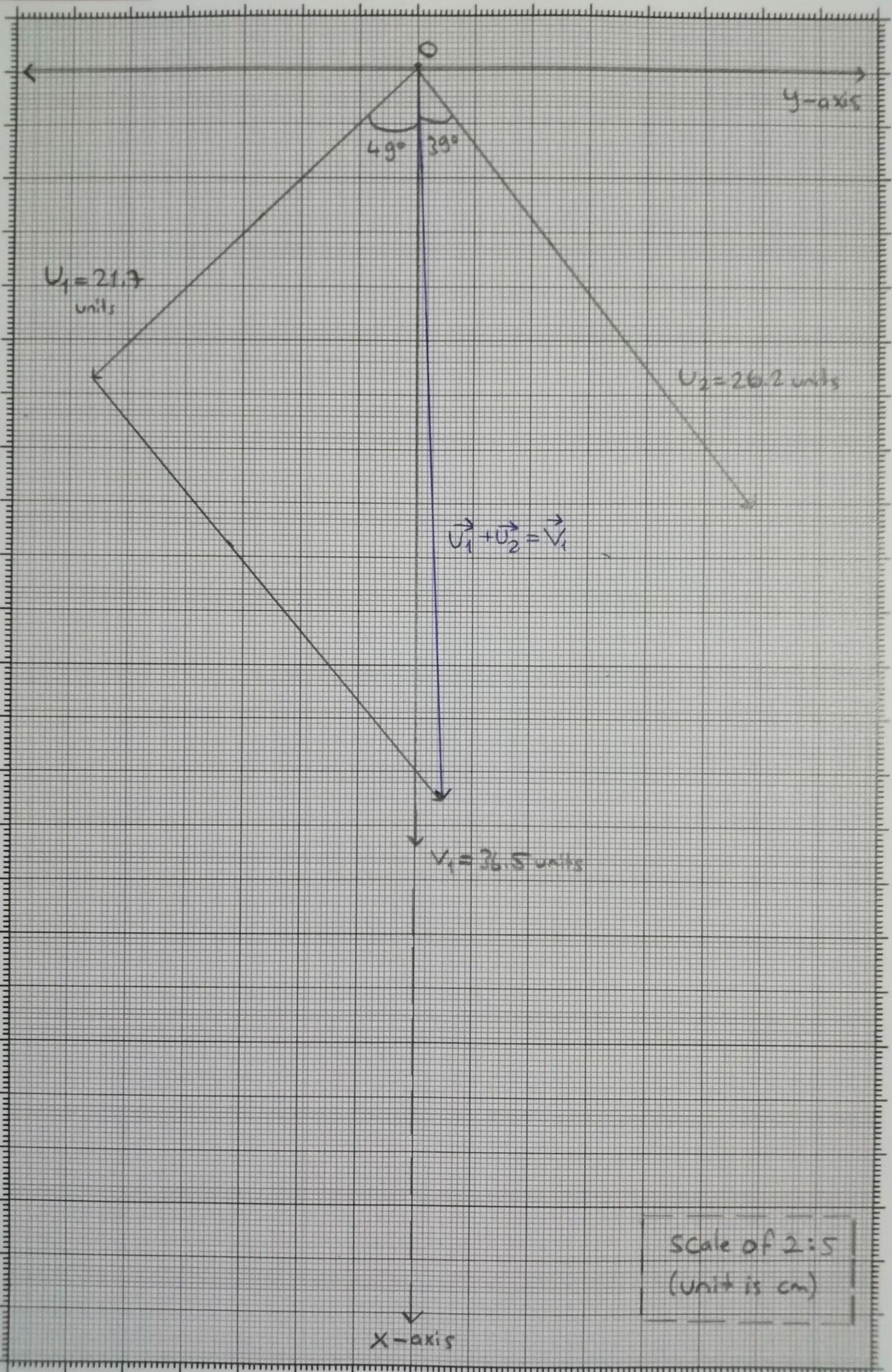
Theorical Error of P_x

$$P_{x\,initial} = P_{x\,final}$$

$$584\,g\,cm/s \cong 553,6\,g\,cm/s$$

$$\%\,error = \frac{|P_{x\,initial} - P_{x\,final}|}{P_{x\,initial}} \times 100 = \frac{|584\,g\,cm/s - 553.6\,g\,cm/s|}{584\,g\,cm/s} \times 100$$

$$\%\,error = \frac{30.4\,g\,cm/s}{584\,g\,cm/s} \times 100 = \%\,5.2$$


O
y-axis
49°
39°
U1 = 21.7 units
U2 = 26.2 units
U1 + U2 = V1
V1 = 36.5 units
x-axis
Scale of 2:5
(unit is cm)

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Section II:

Experimental Procedure:

Use the glass ball as the target in this section and repeat the measurements made in Section I here as well.

Data Table:

m_{glass}	m_{steel}	$\lvert\vec{v}_1\rvert$ (cm)	$\lvert\vec{u}_1\rvert$ (cm)	$\lvert\vec{u}_2\rvert$ (cm)	α (°)	β (°)
5g	16g	37.5	23.4	43.7	21	39

Calculations:

Conservation P_x

$$m_1.v_1 = m_1.U_1.\cos\alpha + m_2.U_2.\cos\beta$$

$$16g \times 37.5\,cm/s \cong 16g \times 23.4\,cm/s \times \cos(21) + 5g \times 43.7\,cm/s \times \cos(39)$$

$$600\,gcm/s \cong 349.5\,gcm/s + 169.8\,gcm/s$$

$$600\,gcm/s \cong 519.3\,gcm/s$$

Conservation P_y

$$0 = m_1.U_1.\sin\alpha - m_2.U_2.\sin\beta$$

$$0 \cong 16g \times 23.4\,cm/s \times \sin(21) - 5g \times 43.7\,cm/s \times \sin(39)$$

$$0 \cong |134.2\,gcm/s - 137.5\,gcm/s|$$

$$0 \cong 33\,gcm/s$$

Theorical Error of P_x

$$P_{x\,initial} = P_{x\,final}$$

$$600\,gcm/s \cong 519.3\,gcm/s$$

$$\%\,error = \frac{|P_{x\,initial} - P_{x\,final}|}{P_{x\,initial}} \times 100 = \frac{|600\,gcm/s - 519.3\,gcm/s|}{600\,gcm/s} \times 100$$

$$\%\,error = \frac{80.7\,gcm/s}{600\,gcm/s} \times 100 = \%\,13.45$$

Conservation KE

$$\frac{1}{2} m_1 . v_1^2 = \frac{1}{2} m_1 . u_1^2 + \frac{1}{2} m_2 . u_2^2$$

$$\frac{1}{2} \times 16g \times (37.5 cm/s)^2 \cong \frac{1}{2} \times 16g \times (23.4 cm/s)^2 + \frac{1}{2} \times 5g \times (43.7 cm/s)^2$$

$$11250 \, gcm^2/s^2 \cong 4380.5 \, gcm^2/s^2 + 4774.2 \, gcm^2/s^2$$

$$11250 \, gcm^2/s^2 \cong 9154.7 \, gcm^2/s^2$$

$\frac{m2}{m1}$

$$\frac{m_1 . V_1}{m_1} = \frac{m_1 . U_1 . \cos\alpha}{m_1} + \frac{m_2 . U_2 . \cos\beta}{m_1}$$

$$V_1 = U_1 . \cos\alpha + U_2 . \cos\beta . \frac{m2}{m1}$$

$$37.5 cm/s = 23.4 cm/s . \cos(21) + 43.7 cm/s . \cos(39) . \frac{m2}{m1}$$

$$37.5 cm/s - 21.8 cm/s = 34.0 cm/s . \frac{m2}{m1}$$

$$\frac{15.7 cm/s}{34.0 cm/s} = \frac{m2}{m1} = 0.462$$

Theorical Error of m2/m1

Theorical measurement $\rightarrow$ $m1 = 16g$, $m2 = 5g$ $\rightarrow$ $\frac{m2}{m1}$ theorical $= \frac{5}{16}$

$$\% \text{ error} = \left| \frac{\frac{m2}{m1} \text{theorical} - \frac{m2}{m1} \text{experiment}}{\frac{m2}{m1} \text{theorical}} \right| \times 100$$

$$\% \text{ error} = \left| \frac{0.3125 - 0.462}{0.3125} \right| \times 100 = \% \, 47.8$$

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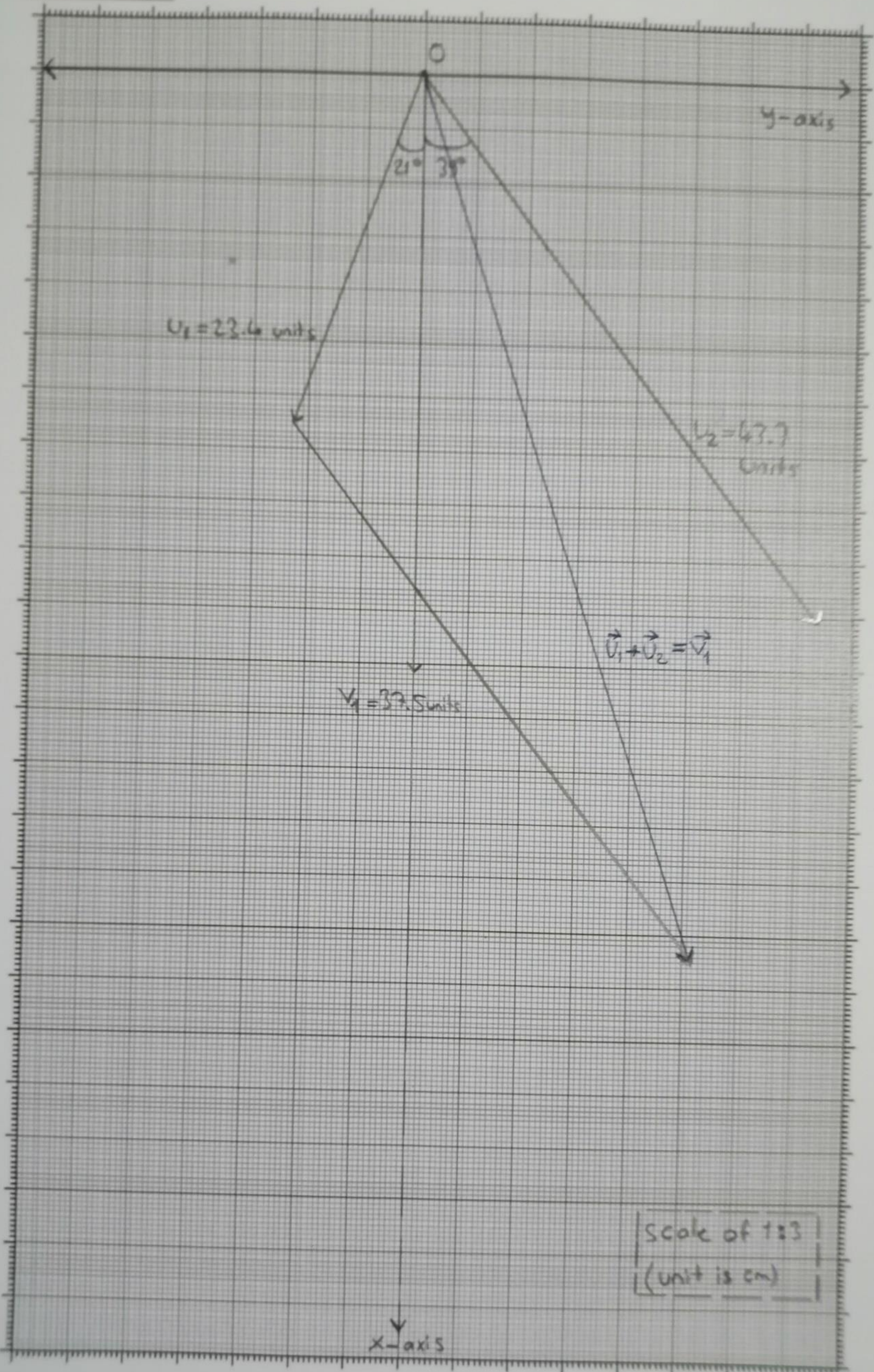

In this experiment, two balls were crashed into each other. The purpose of these section is to predict the change in the speed of the balls. We used conservation of momentum and energy to calculate this. In the experiment, we used the horizontal shot feature to observe the velocity of the balls. In this way, they will travel a certain distance horizontally in the same time and their speed will be at the same rate as those roads.

Balls of equal mass are used in Section-I and the momentum rate on the x-axis is 5.2%. Variable value in momentum conservation is speed, so speeds are directly related to energy. In the experiment, we only calculate the translational kinetic energies of two balls. We neglect rotational kinetic energies caused by friction, so this causes an error rate. In other words, kinetic energy is conserved but we have not calculated the part that we neglected. This is the reason for the difference in vector velocity representation.

Balls of diffrent mass are used in Section-II and the same conditions were realized with the first experiment but the error rate in the momentum of x-axis was 13.45%. In addition, the error rate of the masses is quite high (48.8%). The reason for this is the same as the error in Section-I. However, these is a big diffrence in the vector representation on the graphic. The reason for this is entirely due to mass differences, So it is completely wrong to make vector notation in Section-II. The correct equation is "$V_1 = U_1 + (m_2/m_1) \times U_2$".

Finally, the measurements made with ruler, the measurements made by the weigher and the degree measurement during the vector shift process affect the error rates. The error rates of the experiment in momentum and kinetic energy are acceptable in real life and confirm the theories given.