Physics 11 Non-Conservative Work Lab

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1-4
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Objective and purpose

This lab is designed to explore the relationship between distance(d) and work done by non conservative force(Wnc) for a ball rolling down on a plane. The lab will be made to observe and record the motion of the ball as it rolls down from the incline plane and to measure the time the ball takes to roll down to the bottom and distance the ball has travelled in order to calculate the final velocity (Vf) of the ball and figure out the kinematic energy (KE) of the ball as well.

Problem and question

Since the dependent variable is work done by non conservative forces (Wnc) and independent variable is the distance (d), does the Wnc of the ball has a linear relationship with the distance the ball has travelled in this rolling ball experiment and does the Wnc of the ball increases as the longer distance that the ball has travelled?

Background

In this non conservatice work lab, it is supposed that the work done by the non conservative forces (Wnc) of the ball could be determined by measuring the time it takes to roll different distances, and therefore the Wnc will be determined by the distance the ball has travellled on the plane. Wnc is the work done by non conservative forces, and it equals the total amount of energy of gravitational potential energy (PE) and kinematic energy (KE), which makes Wnc=KE+PE. In this lab, when a small ball rolls down from the plane, its potential energy(PE) decreases due to the decrease of height since "PE=mgh" (m-mass, g-9.8N/Kg, h-height) and meanwhile, its kinematic energy increases due to the increase of velocity of the ball since "KE=1/2mv^2" (m-mass of the ball, v-final velocity of the ball). In this lab, the ball rolling down from the plane mainly involves the forces of friction (Ffr) and gravity (fg). Potential energy (PE) is mainly about the work done by gravity which is a conservative force, and then as the ball rolls down from the plane, its gravitational potential energy (PE) transformed into the kinematic energy (KE) gradually. In addition, potential energy (PE) will be negative because the height of ball decreases and kinematic energy (KE) will be positive because the velocity of the ball increases, and therefore PE+KE basically equals the work done by the force of friction (Ffr) which is a non conservative force, that makes the equation of Wnc=PE+KE.

Hypothesis

In this lab, if the ball has rolled down from exactly the same plane for a longer distance (d), then its work done by non conservative force (Wnc) would be greater.

Variables Description

Variable Description demonstrates those factors which are changing, which are being changed and measured, and which are being held the same for a fair test in this lab.

Materials

In this lab, the following materials are needed in order to complete the trials.

-A metal ball:about 1.0 cm diameter, mass about 10g
-A meter stick or ruler and a triangular ruler
-A stopwatch or a smart phone

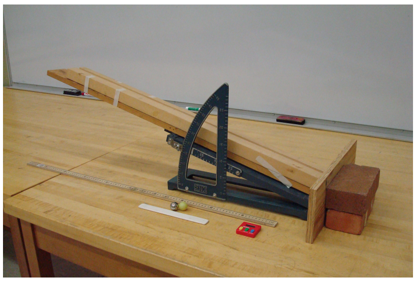
(Variables Description)

Table 1

A table

Independent	Dependent	Controlled
Distance, d(m)	Time, t(s)	Slope of plane(theta)
	Height, h(m)	
	Vf (m/s)	
	ΔPE (J)	
	KE(J)	
	Wnc (J)	

-A scientific calculator
-A wooden plane
-Masking tape
-A wooden plate



Procedures

Part1: Setting up the tools

1.Using the marking tape to label the different lengths of the plane (2.20m, 2.00m, 1.80m...).

2.Place one end of the wooden plane on the first step of a ladder,and put the other end on the ground.

3.Find a distance(e.g 2.20m) and measure the relative height (e.g 0.56m) and calculate the slope of the plane(e.g theta=6.0)

4.Take out the metal ball , the stopwatch or smart phone, a meter stick and a ruler and get ready to use them to measure the factors.

5.Take out a pen or a pencil, paper, and a calculator, and draw a table for the factors such as distance, height, and time on the paper and prepare to record the data from the experiment.

Part 2: Measurement

1.Place the metal ball on the exact position (marking tape) and record the distance and measure the relative height.

2. Release the ball and let the ball roll down and hit the plate on the bottom, and the recorder uses the stopwatch to record the exact time that the ball hits the plate by hearing the sound of crashing.

3.Since it is impossible to measure the exact time, and for avoiding as much uncertainties as possible, rolling the ball down from the same distance and height on the plane for three times and calculate the average time to minimize the uncertainties and errors in the measurement.

4.Record the distance, height, and average time for each different distance in each trial on the paper.

5. After complete recording data for different distances of one slope of the plane, adjusting the position of the plane and changing the slope of the plane(change theta)

6. Measure the distance, height, and time for each trial in every different slope of the plane.

Part3: Calculation

1.Use the kinematic equation "d=(Vo+Vf)/2*t" to calculate the final velocity(Vf=2d/t, since Vo=0 m/s).

2.Measure the mass of the metal ball in kilogram (e.g mass of ball=0.00835 kg).

3.After calculating the final velocity, use the formula "ΔPE=mgΔh" (m-mass of the ball, g=9.8N/kg, h-height) to calculate the change in gravitational potential energy.

4.In order to calculate the change in kinematic energy, the mass of metal ball need to be measured, and then use the formula " ΔKE= 1/2mv^2 " (m-mass of the ball, v-final velocity of the ball) to calculate the change in kinematic energy.

5.Finally, calculate the work done by non conservative force (Wnc) by using the work and energy principle "Wnc=ΔPE+ΔKE".

Data Colllecting and Processing:

(Raw data of rolling ball experiment)
Figure 1. (
Theta=6.0, [slope of plane],mass of ball,m=0.00835 kg)

d(m)	h(m)	t(s)	Vf(m/s)	ΔPE(J)	Δ KE(J)	Wnc(J)
2.20	0.23	2.98	1.477	-0.0188	0.0091	-0.0097
2.00	0.21	2.72	1.471	-0.0172	0.0090	-0.0082
1.80	0.20	2.56	1.406	-0.0164	0.0083	-0.0081
1.60	0.18	2.43	1.317	-0.0147	0.0072	-0.0075
1.40	0.16	2.12	1.321	-0.0131	0.0073	-0.0058
1.20	0.14	1.89	1.269	-0.0115	0.0067	-0.0048
1.00	0.13	1.91	1.047	-0.0106	0.0046	-0.0060
0.80	0.11	1.65	0.9697	-0.0090	0.0039	-0.0051

(raw data of rolling ball experiment)
Figure 2. (
Theta=14.8, [slope of the plane], mass of the ball, m=0.00835 kg)

d(m)	h(m)	t(s)	Vf(m/s)	ΔPE(J)	Δ KE(J)	Wnc(J)
2.20	0.56	1.59	2.77	-0.0458	0.0320	-0.0138
2.00	0.53	1.48	2.70	-0.0434	0.0304	-0.0130
1.80	0.49	1.48	2.43	-0.0401	0.0247	-0.0154
1.60	0.44	1.50	2.13	-0.0360	0.0189	-0.0171
1.40	0.39	1.40	2.00	-0.0319	0.0167	-0.0152
1.20	0.34	1.11	2.16	-0.0278	0.0195	-0.0083
1.00	0.29	1.08	1.85	-0.0237	0.0143	-0.0094
0.80	0.23	0.87	1.84	-0.0188	0.0141	-0.0047

(raw data of rolling ball experiment)
Figure 3. (
Theta=20.0, [slope of the plane],
mass of the ball, m=0.00835 kg)

d(m)	h(m)	t(s)	Vf(m/s)	ΔPE(J)	Δ KE(J)	Wnc(J)
2.20	0.75	1.46	3.01	-0.0614	0.0378	-0.0236
2.00	0.68	1.42	2.82	-0.0556	0.0332	-0.0224
1.80	0.62	1.30	2.77	-0.0507	0.0320	-0.0187
1.60	0.55	1.16	2.76	-0.0450	0.0318	-0.0132
1.40	0.48	1.11	2.52	-0.0393	0.0265	-0.0128
1.20	0.41	1.03	2.33	-0.0336	0.0227	-0.0109
1.00	0.35	0.94	2.13	-0.0286	0.0189	-0.0097
0.80	0.29	0.96	1.67	-0.0237	0.0116	-0.0121

(raw data of rolling ball experiment)
Figure 4. (
Theta=24.1, [slope of the plane], mass of the ball, m=0.00835 kg)

d(m)	h(m)	t(s)	Vf(m/s)	ΔPE(J)	Δ KE(J)	Wnc(J)
2.20	0.90	1.29	3.41	-0.0736	0.0485	-0.0251
2.00	0.83	1.25	3.20	-0.0679	0.0428	-0.0251
1.80	0.76	1.25	2.88	-0.0622	0.0346	-0.0276
1.60	0.68	1.15	2.78	-0.0556	0.0323	-0.0233
1.40	0.60	1.02	2.74	-0.0491	0.0313	-0.0178
1.20	0.51	0.93	2.58	-0.0417	0.0278	-0.0139
1.00	0.42	0.96	2.08	-0.0344	0.0181	-0.0163
0.80	0.33	0.88	1.82	-0.0270	0.0138	-0.0132

(raw data of rolling ball experiment)
Figure 5. (
Theta=30.0, [slope of the plane], mass of the ball, m=0.00835 kg)

d(m)	h(m)	t(s)	Vf(m/s)	ΔPE(J)	Δ KE(J)	Wnc(J)
2.20	1.11	1.10	4.00	-0.0908	0.0668	-0.0240
2.00	1.02	1.09	3.67	-0.0835	0.0562	-0.0273
1.80	0.92	1.04	3.46	-0.0753	0.0500	-0.0253
1.60	0.82	0.96	3.33	-0.0671	0.0463	-0.0208
1.40	0.72	1.01	2.77	-0.0589	0.0320	-0.0269
1.20	0.62	0.94	2.55	-0.0507	0.0271	-0.0236
1.00	0.52	0.75	2.66	-0.0425	0.0295	-0.0130
0.80	0.42	0.75	2.13	-0.0344	0.0189	-0.0155

Figure 6. Graph 1: Theta=6.0

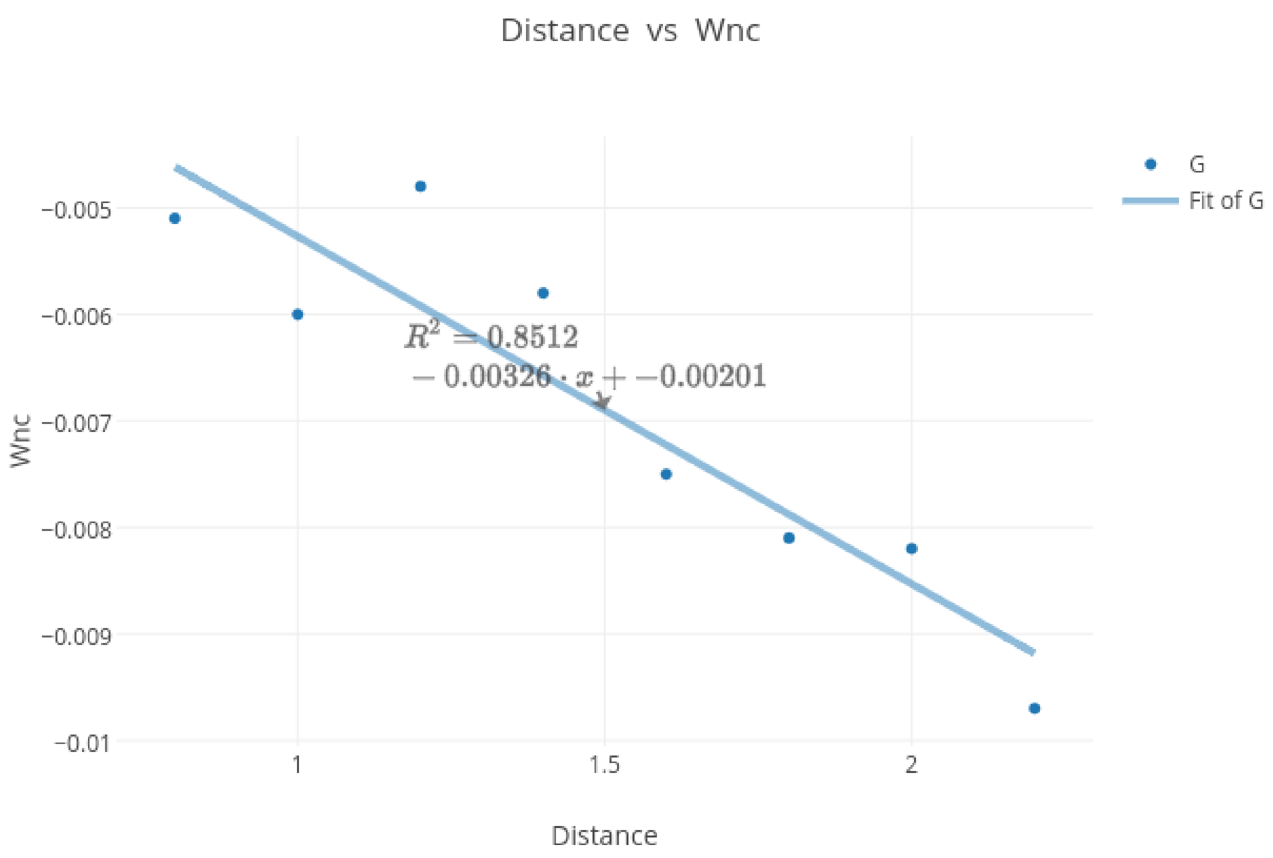


Figure 7. Graph 2: Theta=14.8

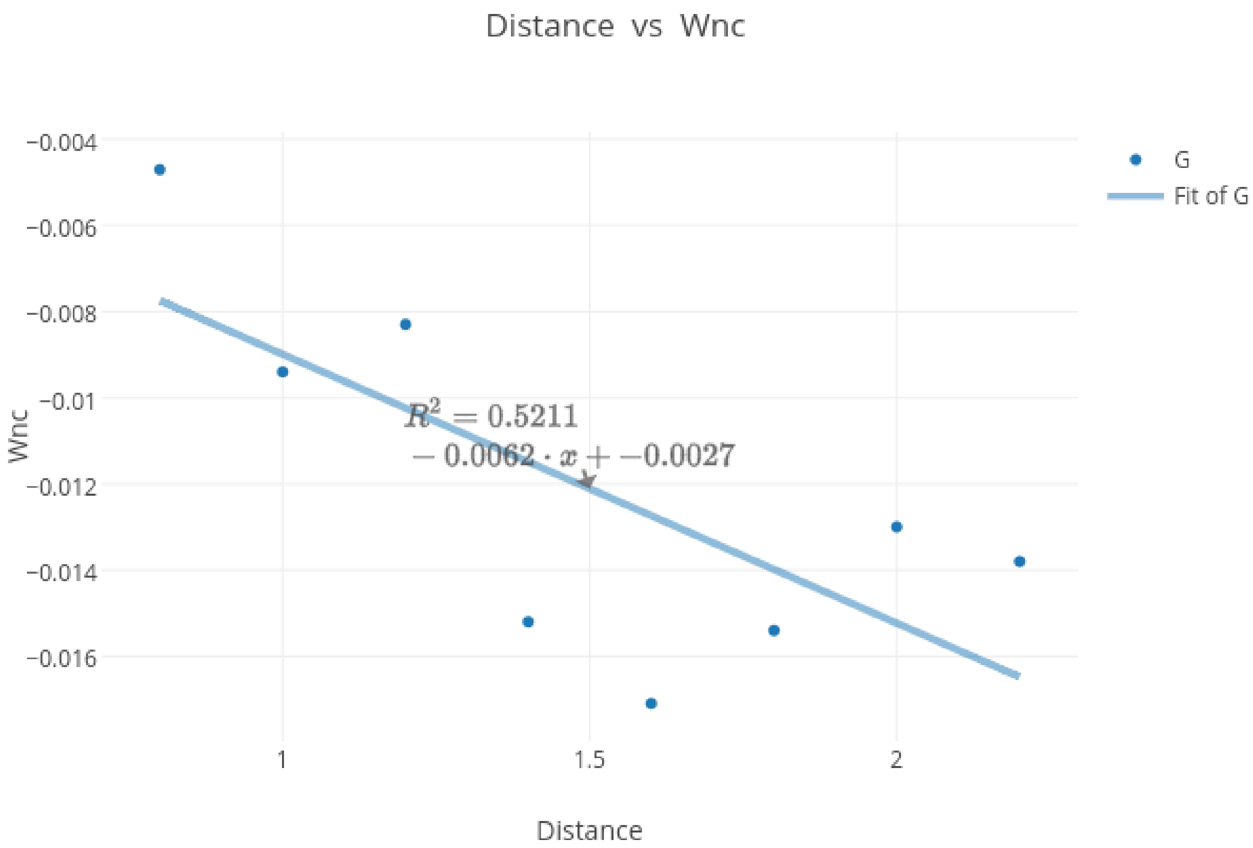


Figure 8. Graph 3: Theta=20.0

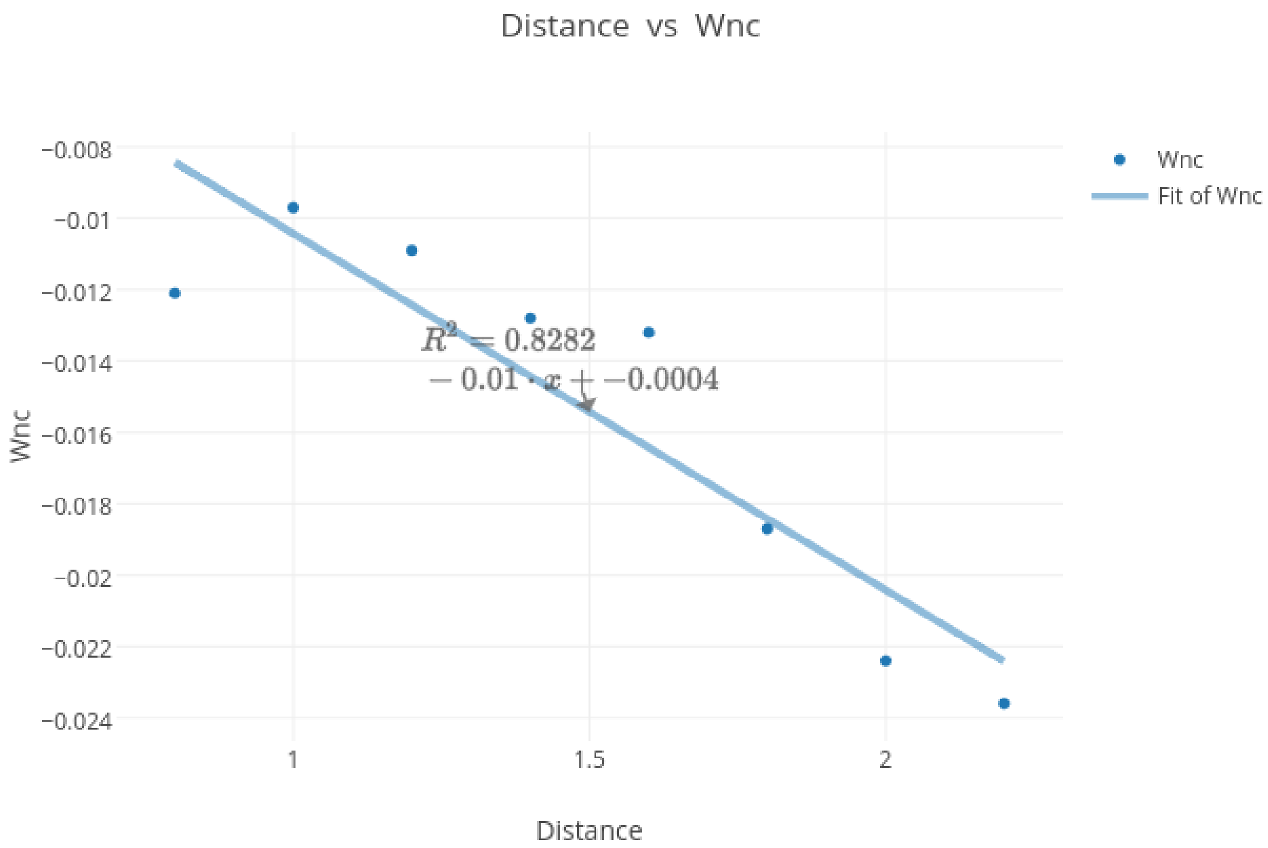


Figure 9. Graph 4: Theta=24.1

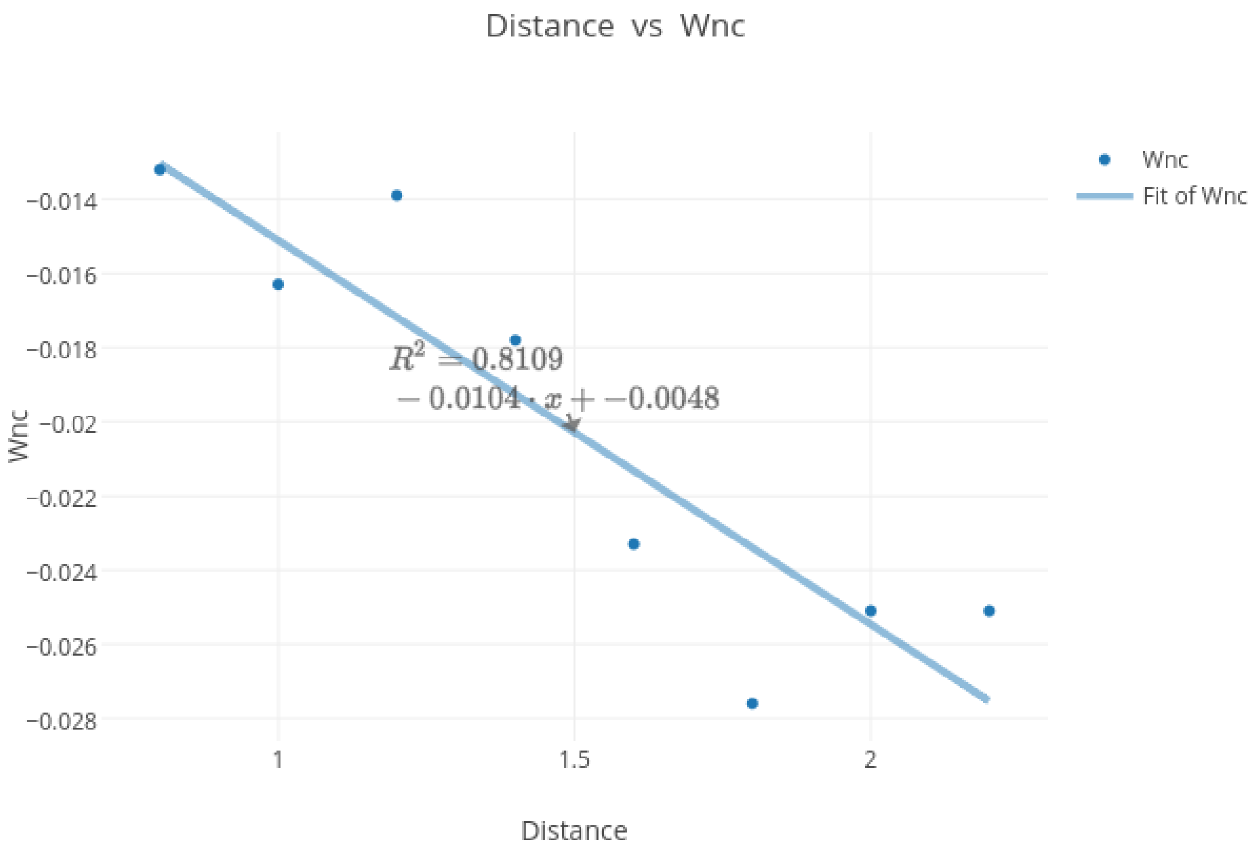
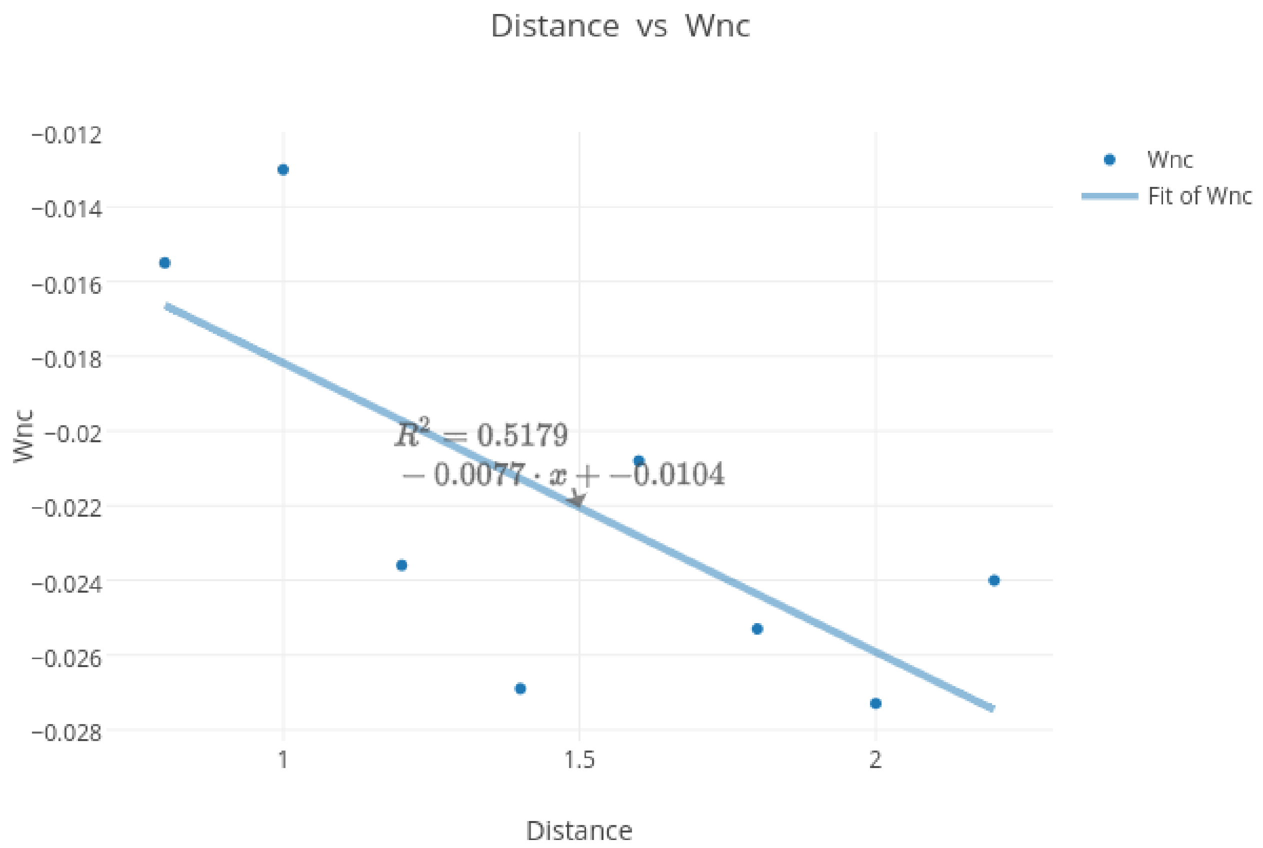


Figure 10. Graph 5: Theta=30.0



Conclusion and Evaluation

Conclusion

In conclusion, since the work done by friction (Wnc)is negative, this lab illustrates that work done by friction which is non conservative force (Wnc) increases as the greater distance that the ball has travelled. As for the question mentioned before, the results of the experiment proves that Work done by non conservative force, Wnc of the ball has a linear relationship with the distance that the ball has travelled and Wnc of the ball increases as the ball has travelled for a greater distance on the plane.

In addition, since the results of the rolling ball experiment cannot be absolutely accurate, there are technical and random errors and uncertainties. In general, the data that gained from the experiment follow the similar trends which is that Work done by friction(Wnc) increases as the distance increases. However, the results from few trials are not clear and accurate(e.g in Figure 5(theta=30.0), when the distance is between 1.80m - 2.20m, Wnc shows a downward trend as the distance increases, which is the opposite of the conclusion).

Evaluation

Compare the measured value to the literature value, the actual data of the experiment differs from the theoretical data because there are still weakness in the design and method of the experiment. But generally, the results follow a scientific and logical trends and they can be very reliable and reasonable and close to the true values. However, a lot of good methods and designs for improvements can be employed in order to perform this lab better and achieve more precise and reliable results and conclusion.

Suggestions for Improvements

The errors and problems	How that error affected data	A suggestion for improvements
Time of reaction of releasing the ball	The Recorded Time was either shorter or longer, kinematic energy KE was either higher or lower than it should have been	Record videos for the movement of the ball and measure accurate time on the computer
Force of Friction increases due to the Tilted plane	Recorded time appeared longer, kinematic energy(KE) and Wnc were lower than it should have been	Put the plane on a flat and stable surface and support it with heavy objects(e.g books).