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THE STUDY OF MOTION ALONG INCLINED PLANE

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Abstract: Kinematics is the study of motion. There are different types of motion such as random motion, linear motion rotational motion etc. Kinematics equation describes the motion of objects & system without considering the forces. SC-photogate software can calculate the time. This experiment deals with linear (straight line) acceleration. Kinematics equation can be used to calculate velocity, acceleration time displacement.

Keywords: Time, Motion, Displacement, Distance, Velocity.

Introduction: Kinematics developed in classical mechanics that describes the motion of objects & system without considering the forces. Kinematics equation describing the initial condition of any value of position, acceleration / velocity. Kinematics is the study of motion. There are different types of motion such as random motion, linear motion rotational motion etc. Kinematics equation can be used to calculate velocity, acceleration time displacement.

The 1st part of the 17th century Galileo experimentally determine the concept of a acceleration using inclines. If the angle of the incline is small, a ball rolling down an incline moves slowly and can be accurately timed. In the first part of this experiment, you will roll a ball down a ramp and determine the ball's velocity with a pair of photogates. The photogates can record the time when the ball passes through them (breaking an infrared beam) and then the SC-photogate software can calculate the time it took the ball to travel between the 2 photogates. Using the time and the distance, you will then graph distance vs. time and acceleration vs. time graphs. This experiment deals with linear (straight line) acceleration. We will therefore consider only the motion of the center of the cart, which moves in a straight line parallel to the inclined plane. The velocity at any instant in time can be found by finding the slope of the distance time graph at that instant in time. You will let a cart roll down an inclined plane from a position of rest. It will accelerate slowly if the angle is small. The relationship between distance, time, and acceleration will then be established.

THE KINEMATIC EQUATIONS

$$d = v_i t + \frac{1}{2} a t^2$$

$$v_f^2 = v_i^2 + 2ad$$

$$v_f = v_i + at$$

$$d = \frac{v_i + v_f}{2} t$$

Experimental setup

Apparatus:

Cart, masses, meter stick, photodetector, SC photogates software, and weight scale, Windows-based computer, ramp, connecting wires, protecter, computer etc.

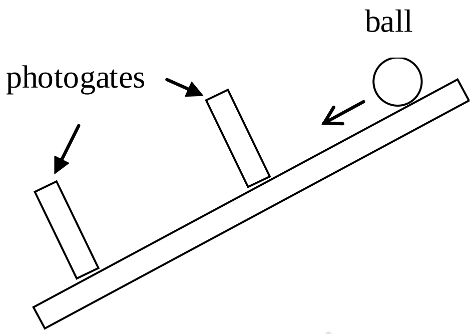

Diagram:

Figure 1: Experimental setup

Procedure:

1. Configure the wooden track as shown in Fig. 2. Set the inclination of the track to approximately $7° - 12°$, but measure h and d to determine the angle θ accurately. (Note that the inclination of the track is greatly exaggerated. The experiment will work equally well at larger inclination angles, but you may encounter more difficulties in timing the travel using the stopwatch.). We can use **SC PHOTOGATE software**.

2. Place the cart on the track at least 41cm from the end-stop. Try a few trails runs to see cart behaves as you allow it to roll on the incline. Do you observe that the cart starts from rest and the speed increases and appears to have its maximum velocity just as it collides with the end stop?

3. Next use the stopwatch (on the photogate timers) to measure the time the cart takes to travel the distance s down the incline. Repeat your measurements at least six times (each partner must do at least two trails.) Note the individual times and the average time along with the distance s in your notebook. Are all the recorded times the same? How confident are you that you started the SC-photogate as the cart was released and stopped the timer when the car collided with the end-stop?

4. To avoid human errors introduced in measuring time, we will use the photogate timers. The timers consist of two photogates. The timer is triggered when the light beam in the first photogate is interrupted and will stop when the light beam in the second photo diode is interrupted. Ensure that the two photo diodes are connected to each other, and the mode switch is set to "pulse" and the memory is turned on. You can test that the timer works bypassing your hand between the U-shaped arms and across the two beams. Now repeat part 2 by using the photogate times. You will have to adjust the height and location of the gates. The cart should cut across the first photogate just after you release the cart and then cut across the beam of the second photogate just before it hits the end-stop. Check with the instructor if your setup is working properly. Do the measurements at least three times and calculate the average value.

5. Position two photogates so the ball, car, rolls through each of the photogates while rolling on the ramp surface. Record the distance between the photogates in the table. Approximately center the detection line of each photogate on the middle of the ball. Connect Photogate 1 to 2

Photogates prevent accidental movement of the Photogates, use tape to secure the ring stands in place.

6.Roll the ball down the ramp starting at the first photogate (from rest). Make sure that the ball does not strike the sides of the photogates (reposition them if necessary). If the red LED comes on when the ball passes through the Photogate, the experimental set up works properly.

7.Prepare the computer for data collection by opening “SC Photogate software in the Physics with Computers experiment. A data table and two graphs are displayed; one graph will show the time required for the ball to pass through the Photogates for each trial.

8.Carefully measure the distance from the beam of Photogate 1 to the beam of Photogate 2. To obtain accurate results, you must enter an accurate measurement. Record the distance between the photogates in the table. In addition, estimate the uncertainty in this distance, □x based on your measurement device and the way you perform this measurement.

9. Next, increase the angle θ in steps and measure the time t for at least five10 trials. (Each trial should be repeated 3 times to minimize error in determining time t.) lot the distance s versus time t, and the distance s versus the square of the time t. Can you draw a straight line through any of the graphs? Should this line pass through the origin? Determine the slope and hence the acceleration. According to our discussion earlier, dividing the acceleration by the sine of the angle of inclination should give us the acceleration due to gravity. How do these values compare?

10. Draw a smooth curve that best describes the graph. The curve should pass through the origin. Draw tangents to the curve at four equally spaced time intervals to the graph. The slope of the line corresponds to the velocity of the cart at that time. Why? Plot the obtained velocity versus time t. Can you fit a straight line through your data? Does it increase, decrease, or remain constant with time? How does this compare with qualitative observation that the velocity increases as the cart travels further down the track?

11. Next, we investigate if the acceleration depends on the mass of the cart. Use the two supplied masses and choose the same distance d as you had in your first trial (step 3). Measure the time t for at least 6 trials as before. Calculate the acceleration directly using the formula $a = \frac{2s}{t^2}$ (here v= 0) which you have already verified earlier. Is the acceleration corresponding to the three masses of the cart constant?

12. Next, increase the angle of inclination of the track by increasing the height h by 1-2 cm. the same distance s and calculate the acceleration. Does the acceleration change? Measure the acceleration for at least two more angles of inclination.

Observation Table & calculation

Table No.1

For Solid ball 1.

Angle- 7.89

Distance (s) = 40-41cm

N	t	dt	v	dv	a=gsin(7.89))*5/7	a=2(s-ut)/t^2
1	33.3049	0.7013	0.247892			
2	34.0062	6.545	0.563361	0.315469	0.960901672	0.952187938
3	47.4631	0.691	0.256908			
4	48.1541	6.9284	0.561847	0.304939	0.960901672	0.965385312
5	60.1604	0.6956	0.255191			
6	60.856	4.8167	0.562602	0.307411	0.960901672	0.952711302
7	111.446	0.6844	0.268666			
8	112.1305	6.0346	0.575705	0.307039	0.960901672	0.956974304
9	123.7706	0.689	0.264974			
10	124.4597	5.8789	0.567176	0.302202	0.960901672	0.949749069
11	151.4221	0.6871	0.261615			
12	152.1092	4.8775	0.570286	0.308671	0.960901672	0.966919019

Table No.2

For Solid ball 2

N	t	dt	v	dv	a=dv/dt	a=2(s-ut)/t^2
1	20.8306	0.6821	0.355997			
2	21.5128	5.5932	0.805034	0.449037	0.658219	0.675640751
3	31.6895	0.6783	0.360856			
4	32.3678	5.0437	0.812267	0.451411	0.6655035	0.674785694
5	42.7305	0.6843	0.352786			
6	43.4149	4.6199	0.80519	0.452404	0.6610228	0.677343109
7	54.0351	0.6826	0.356909			
8	54.7177	5.2725	0.805147	0.448238	0.6566628	0.671215136
9	65.1435	0.6871	0.354474			
10	65.8306	4.2187	0.803076	0.448602	0.6528919	0.662735821
11	83.5969	0.6839	0.354565			
12	84.2808	4.9776	0.80685	0.452285	0.6613321	0.673536571

Table No.3

For linear motion using car

N	t	dt	v	dv	a=dv/dt	a=g*sin(7.8)
1	4.4868	0.7537	0.848939			
2	5.2405	9.871	1.60069	0.751751	0.9974141	1.194319565
3	64.0784	0.777	0.822257			
4	64.8553	4.8563	1.66389	0.841633	1.0833222	1.194319565
5	69.7117	0.7706	0.840019			
6	70.4823	3.8897	1.6244	0.784381	1.0178835	1.194319565
7	100.3116	0.7669	0.794238			
8	101.0785	4.2908	1.63435	0.840112	1.0954649	1.194319565

Table No.4

For Solid ball 1.

For Angle =12.5634

N	t	dt	v	dv	a=gsin(12.5634)*5/7	a=2(s-ut)/t^2
1	9.0409	0.5612	0.30233			
2	9.6021	6.669	0.685687	0.383357	1.522638534	1.513483758
3	52.4104	0.5543	0.310608			
4	52.9647	6.2332	0.681898	0.37129	1.522638534	1.535109159
5	64.6779	0.5526	0.310087			
6	65.2304	5.417	0.689558	0.379471	1.522638534	1.549912792
7	70.6474	0.5518	0.310216			
8	71.1992	4.5521	0.686977	0.376761	1.522638534	1.555572065
9	75.7514	0.5659	0.29677			
10	76.3172	4.4889	0.682376	0.385606	1.522638534	1.499224023
11	80.8062	0.5543	0.306874			
12	81.3604	4.2804	0.689919	0.383045	1.522638534	1.548582008

Table No.5

For Solid ball 2.

N	t	dt	v	dv	a=dv/dt	a=2(s-ut)/t^2
1	6.2454	0.5537	0.439474			
2	6.799	5.3479	1.02325	0.583776	1.054508671	1.074181384
3	34.7997	0.5593	0.432628			
4	35.359	5.4695	1.01118	0.578552	1.034421598	1.061524344
5	40.8285	0.5595	0.43055			
6	41.388	4.1627	1.01466	0.58411	1.043985702	1.067640823
7	45.5507	0.5539	0.438462			
8	46.1045	4.0421	1.02157	0.583108	1.052921632	1.076486923
9	54.8005	0.5545	0.442329			
10	55.355	3.9719	1.01392	0.571591	1.030822362	1.058499608
11	59.3269	0.554	0.438973			

12	59.8809	4.7595	1.02214	0.583167	1.052648014	1.073967848

Table No.6

For linear motion using car

N	t	dt	v	dv	a=dv/dt	a=g*sin(12.5634)
1	6.6689	0.5825	0.940323			
2	7.2514	7.1011	2.12563	1.185307	2.0348618	2.131126325
5	24.8987	0.5716	0.953735			
6	25.4704	3.8537	2.16128	1.207545	2.11220045	2.131126325
7	29.3241	0.575	0.916342			
8	29.899	4.7374	2.17503	1.258688	2.18940337	2.131126325
9	34.6364	0.5681	0.941387			
10	35.2045	4.5013	2.18017	1.238783	2.18057208	2.131126325
11	65.6668	0.5716	0.938344			
12	66.2384	5.4068	2.15838	1.220036	2.13442267	2.131126325
13	71.6452	0.5726	0.945653			
14	72.2177	4.6215	2.18713	1.241477	2.16851878	2.131126325

Table No.7-

For disc

N	t	dt	v	dv	a=2/3sin(12.56)*9.8	a=2(s-ut)/t^2
1	4.4045	0.6007	0.300142	0.461663	1.420750883	1.428358
2	5.0053	8.7448	0.761805			
3	13.7501	0.6021	0.295589	0.469907	1.420750883	1.43452885
4	14.3522	4.7334	0.765496			
5	33.0573	0.5993	0.304694	0.289357	1.420750883	1.42218809
6	33.6566	3.832	0.594051			
7	37.4886	0.6028	0.299667	0.45125	1.420750883	1.41653005
8	38.0914	3.7695	0.750917			
9	46.1166	0.6076	0.289178	0.389191	1.420750883	1.42097101
10	46.7243	4.0104	0.678369			
11	50.7347	0.5987	0.305867	0.498631	1.420750883	1.42214164
12	51.3334	3.961	0.804498			

Result and conclusions:

From Newton's second law, show that the theoretical acceleration of a body down a frictionless inclined plane is a = g sin θ.

From kinematics, derive an equation that yields the acceleration of a body in terms of the distance it travels and the time it takes initial velocity. (a=2(s-ut)/t^2)

Both calculated and experimental acceleration are same…….!

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