Practical-2

One Dimensional motion on an Inclined Plane

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Reports

Aim

Aim of this experiment of is to find the position-time and velocity time variation due to constant acceleration of an object going down on an inclined plane and its kinematic equations.

Introduction

Newton's first law states that an object will remain at rest or in uniform motion in a straight line unless acted upon by an external force. Velocity is defined as the change in distance with respect to time. The mathematical relation is given below

$v=x-x_0/t$ …(i)

or

$x=x_0+vt$ …(ii)

for the first equation of motion, acceleration is defined as the rate of change of velocity with respect to time i.e.

$a=dv/dt$ …(iii)

$adt=dv$

integrating both sides

(time from 0 to t and velocity from v_0 to v)

$\int_0^t adt=\int_{v0}^{v} dv$

$a[t]_0^t=[v]_{v0}^{v}$

$at=v-v_0$

$v=v_0+at$ …(iv)

equation(iv) is the first equation of motion which tells the variation of velocity with time and constant acceleration. Furthermore, velocity is defined as the rate of change of displacement with respect to time.

this implies that $v=dx/dt$ …(v)

using equations(iv) and (v)

$dx/dt= v_0+at$

$dx=(v_0+at)dt$

$dx=v_0dt+atdt$

integrating both sides

(x from x_0 to x and t from 0 to t)

$\int_{x0}^{x} dx=\int_{v00}^{t} dt +a\int_0^t tdt$

$[x]_{x0}^{x} =v_0[t]_0^t+1/2a[t^2]_0^t$

$x-x_0=v_0t+1/2at^2$ …(vi)

this equation is the second equation of kinematics, which tells the variation of position with time and constant acceleration.

Experiment method

1. use the dynamics track and raise it to five centimetres from one side.
2. Attach the motion sensor at the inclined end pointing downwards to the track. Set the switch to cart icon on motion sensor.
3. set the end-stop at the track's end.
4. Connect the GLX to the motion sensors and set the parameters to the following
    a. Sample rate unit at samples per second
    b. Sample rate at 10
    c. Position at visible
    d. Velocity at visible
    e. Acceleration at not visible
5. Join the picket fence to the car's top.

6. fasten photogate just before the end of the track and positioning it such that the car passes easily underneath it
7. Connect the photogate to GLX and set the parameters as follows
    a. Time in gate-visible
    b. Velocity-visible
    c. All other parameters-not visible
8. Create a Position-time graph on GLX.
9. Keep the car 15 centimetres in a position ahead of the motion sensor.
10. With the help of other members, start recording data simultaneously on both the GLX and stop watch, when the car is set in motion.
11. When the car reaches the end of the track, hit stop on the stopwatch.
12. Save the data on GLX for later analysis.
13. Repeat it two more times and then change the height from 5centimtres to 7.5 centimetres and 10 centimetres.

Results and calculations

The initial position of car is at 0.15 metres from the motion sensor

1. At height 5 centimetres
    a. Table for position

#	Position 1 (m)	Position 2 (m)	Position 3 (m)	Average position (m)
1	0.203	0.232	0.209	0.214
2	0.215	0.252	0.218	0.228
3	0.230	0.277	0.234	0.247
4	0.252	0.307	0.255	0.271
5	0.278	0.341	0.281	0.300
6	0.309	0.379	0.311	0.333
7	0.345	0.422	0.346	0.371
8	0.386	0.470	0.385	0.413
9	0.430	0.523	0.429	0.460
10	0.480	0.581	0.478	0.513
11	0.535	0.643	0.531	0.569
12	0.595	0.709	0.591	0.631
13	0.658	0.780	0.653	0.697
14	0.726	0.853	0.719	0.766
15	0.798	0.933	0.790	0.840
16	0.873	1.016	0.864	0.917
17	0.955	1.026	0.944	0.975

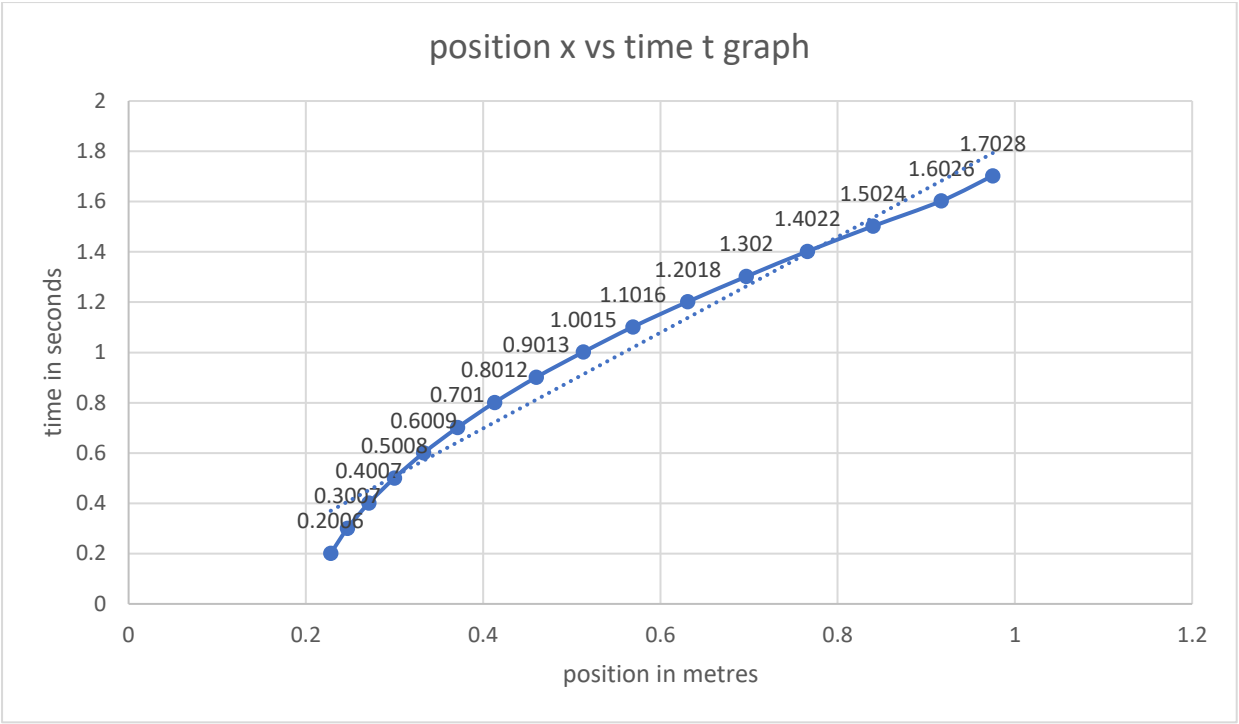
    b. Table for time

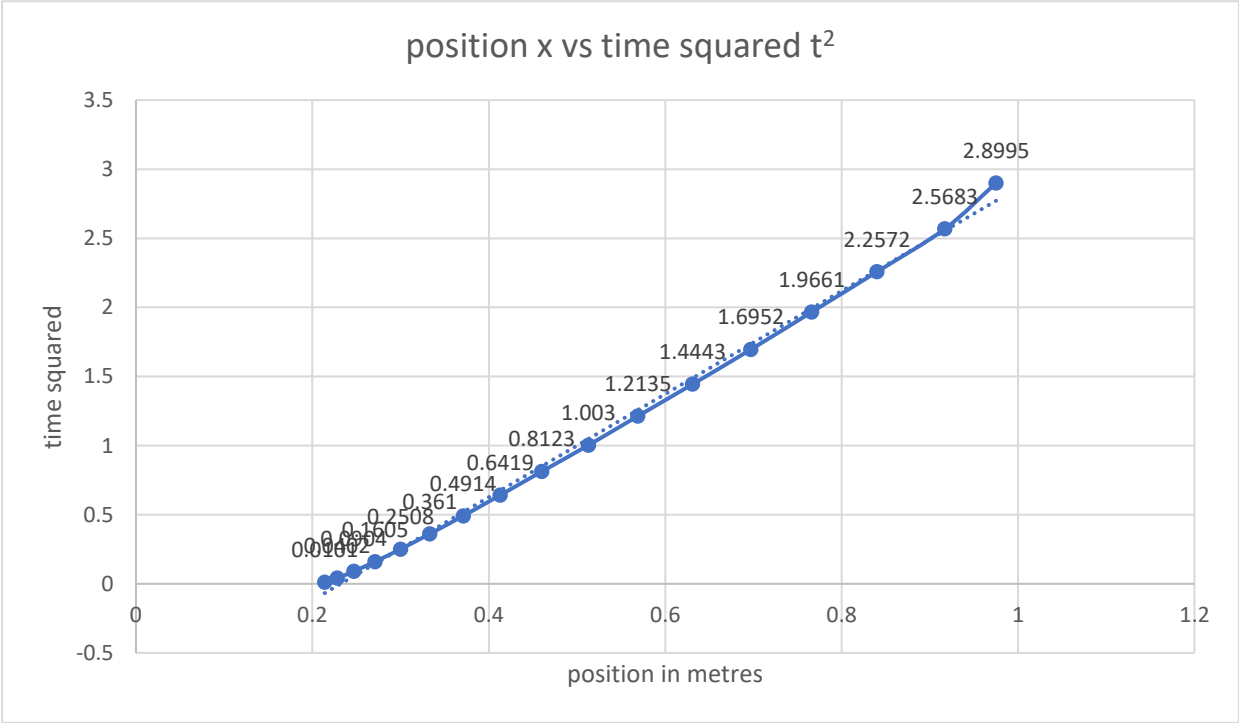
#	Time 1(s)	Time 2 (s)	Time 3 (s)	Time avg(s)	Time avg squared(s^2)
1	0.1006	0.1007	0.1006	0.1006	0.0101
2	0.2006	0.2007	0.2006	0.2006	0.0402
3	0.3007	0.3008	0.3007	0.3007	0.0904
4	0.4007	0.4009	0.4007	0.4007	0.1605
5	0.5008	0.5010	0.5008	0.5008	0.2508

6	0.6009	0.6011	0.6009	0.6009	0.3610
7	0.7010	0.7012	0.7010	0.7010	0.4914
8	0.8011	0.8014	0.8011	0.8012	0.6419
9	0.9013	0.9015	0.9012	0.9013	0.8123
10	1.0014	1.0017	1.0014	1.0015	1.0030
11	1.1016	1.1019	1.1015	1.1016	1.2135
12	1.2017	1.2021	1.2017	1.2018	1.4443
13	1.3019	1.3023	1.3019	1.3020	1.6952
14	1.4021	1.4025	1.4021	1.4022	1.9661
15	1.5023	1.5027	1.5023	1.5024	2.2572
16	1.6025	1.6030	1.6025	1.6026	2.5683
17	1.7028	1.7030	1.7027	1.7028	2.8995

c. Table for velocity

#	Velocity 1(m/s)	Velocity 2(m/s)	Velocity 3(m/s)	Velocity average(m/s)
1	0.10	0.17	0.08	0.11
2	0.14	0.22	0.13	0.16
3	0.18	0.27	0.18	0.21
4	0.24	0.32	0.23	0.26
5	0.29	0.36	0.28	0.31
6	0.34	0.41	0.33	0.36
7	0.38	0.45	0.37	0.40
8	0.43	0.50	0.41	0.44
9	0.47	0.56	0.46	0.49
10	0.52	0.60	0.51	0.54
11	0.57	0.64	0.56	0.59
12	0.61	0.68	0.61	0.63
13	0.65	0.72	0.64	0.67
14	0.70	0.76	0.69	0.71
15	0.74	0.82	0.72	0.76
16	0.78	0.47	0.77	0.67
17	0.76	-0.05	0.81	0.50


position x vs time t graph
time in seconds
position in metres
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0.2006
0.3007
0.4007
0.5008
0.6009
0.701
0.8012
0.9013
1.0015
1.1016
1.2018
1.302
1.4022
1.5024
1.6026
1.7028


position x vs time squared t2
time squared
position in metres
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
0
0.2
0.4
0.6
0.8
1
1.2
0.0161
0.0404
0.1005
0.2508
0.361
0.4914
0.6419
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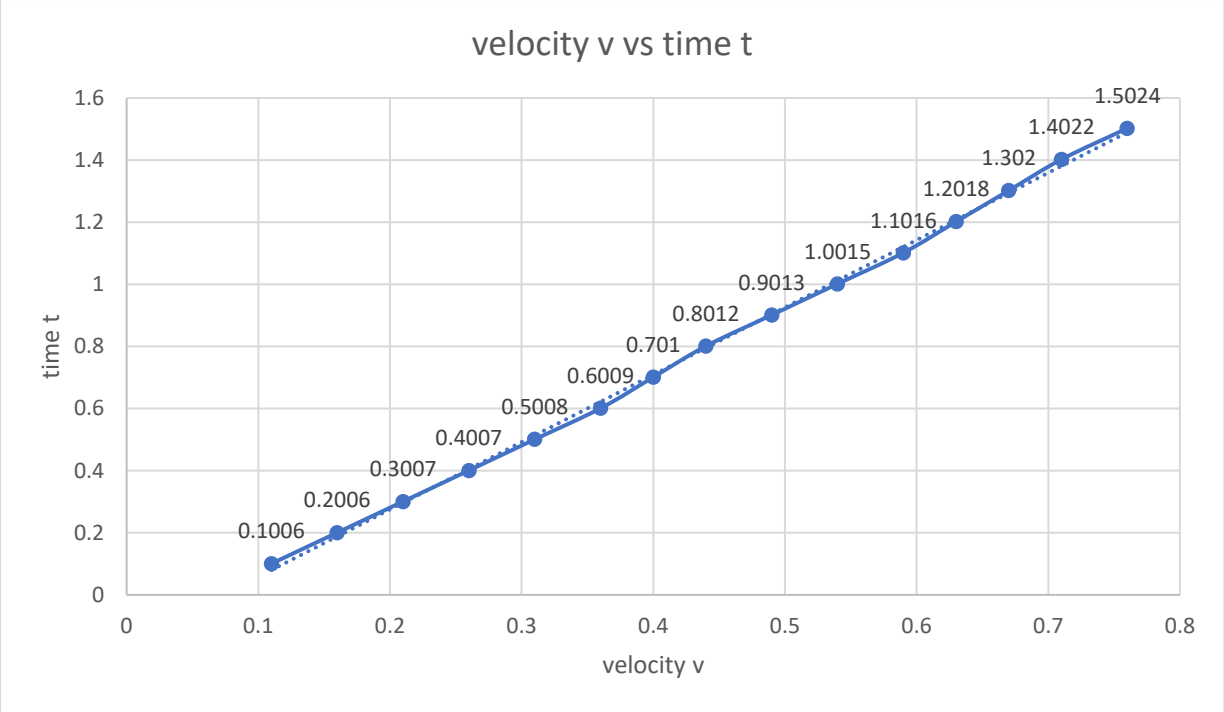
1.4443
1.6952
1.9661
2.2572
2.5683
2.8995



d. Calculations

From graph x vs time squared

y_2=2.5683 y_1=2.2572

x_2=0.917 x_1=0.840

slope1=y_2-y_1/x_2-x_1

=2.5683-2.2572/0.917-0.840

=4.040

From the graph velocity vs time

y_2=1.4022 y_1=1.3020

x_2=0.69 x_1=0.64

slope2= y_2-y_1/x_2-x_1

=1.4022-1.3020/0.69-0.64

=2.004

From above this means, acceleration from x-t^2 graph is 4.040m/s^2 and from v-t graph it is 2.004m/s^2

2. At height 7.5 centimetres

a. Table for position

#	Position 1 (m)	Position 2 (m)	Position 3 (m)	Average position (m)
1	0.232	0.262	0.284	0.259
2	0.256	0.297	0.321	0.291
3	0.288	0.337	0.364	0.329
4	0.326	0.383	0.414	0.374
5	0.370	0.436	0.470	0.425
6	0.421	0.495	0.534	0.483
7	0.478	0.562	0.604	0.548
8	0.544	0.634	0.680	0.619
9	0.615	0.713	0.762	0.696
10	0.691	0.797	0.848	0.778

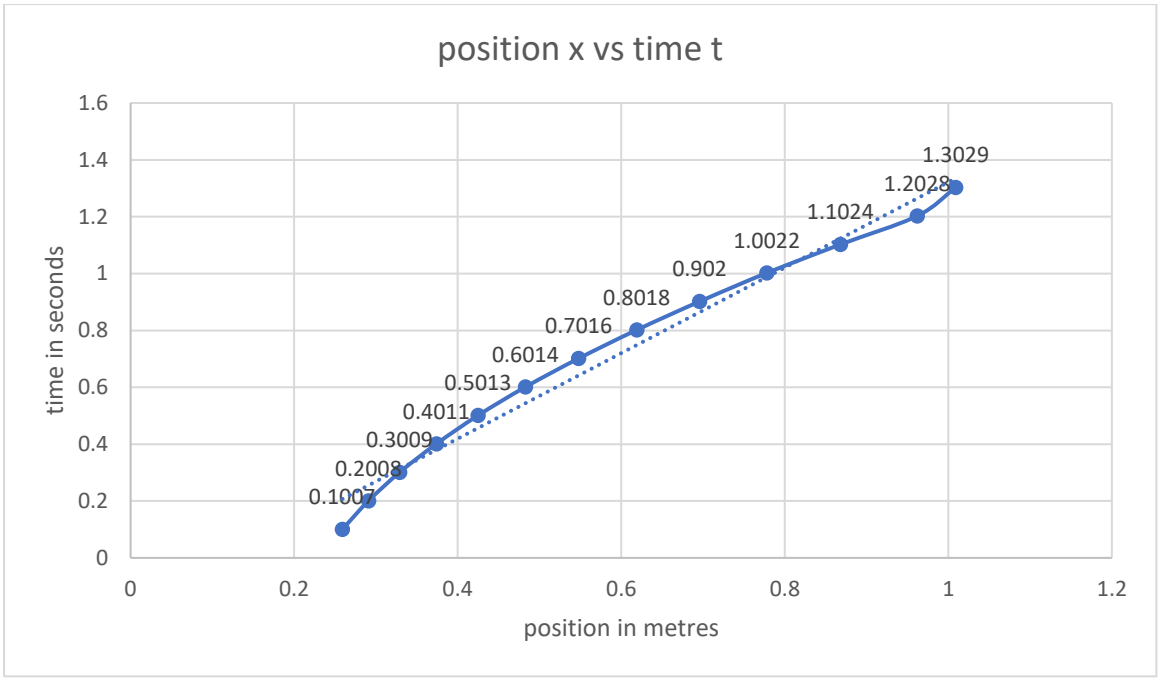
11	0.774	0.887	0.943	0.868
12	0.861	0.984	1.043	0.962
13	0.957	1.042	1.029	1.009
14	1.048	1.020	1.006	1.024

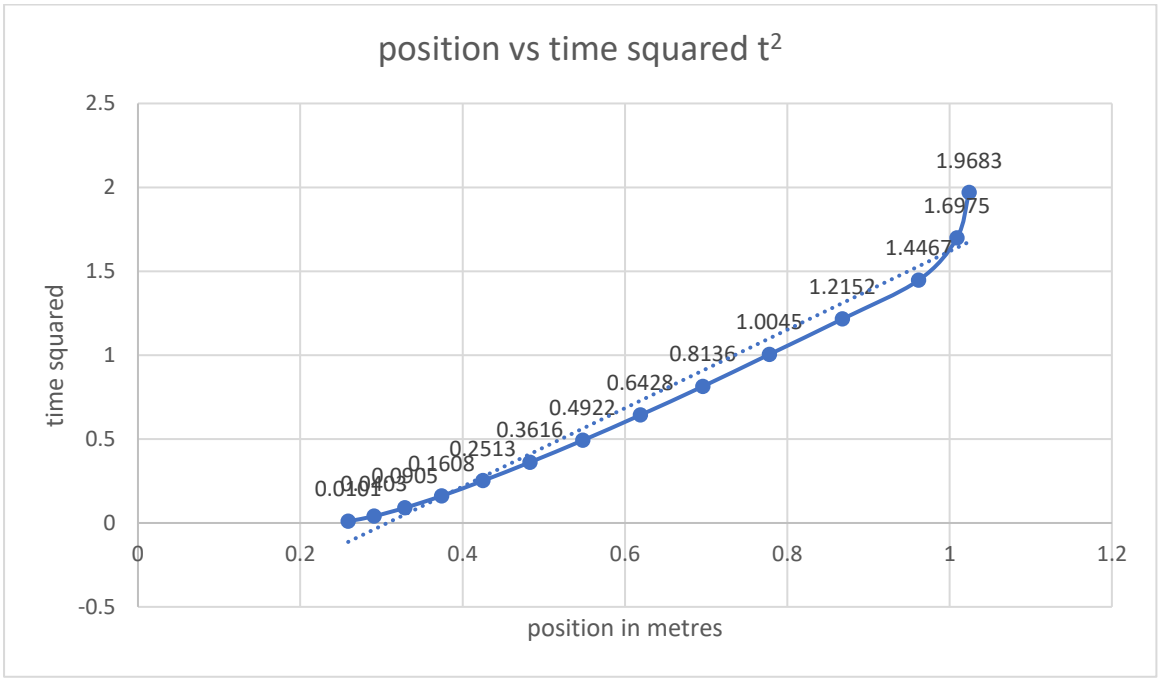
b. Table for time

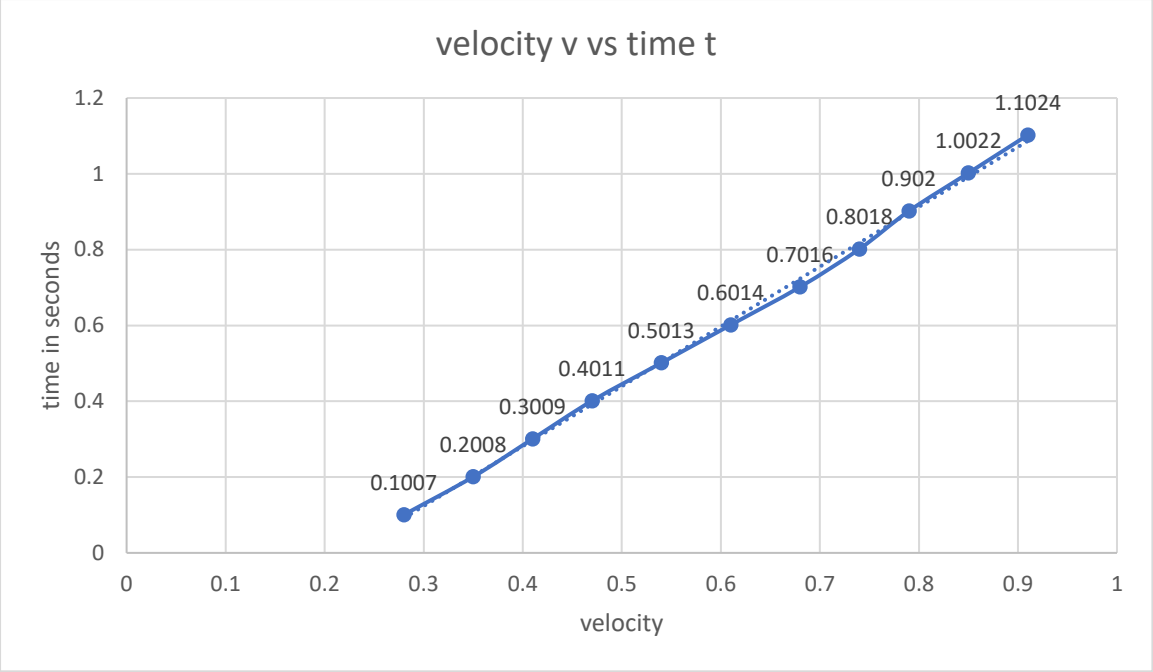
#	Time 1(s)	Time 2 (s)	Time 3 (s)	Time avg(s)	Time avg squared(s^2)
1	0.1007	0.1008	0.1008	0.1007	0.0101
2	0.2007	0.2009	0.2009	0.2008	0.0403
3	0.3008	0.3010	0.3011	0.3009	0.0905
4	0.4009	0.4011	0.4012	0.4011	0.1608
5	0.5011	0.5013	0.5014	0.5013	0.2513
6	0.6012	0.6014	0.6016	0.6014	0.3616
7	0.7014	0.7016	0.7018	0.7016	0.4922
8	0.8016	0.8018	0.8020	0.8018	0.6428
9	0.9018	0.9021	0.9022	0.9020	0.8136
10	1.0020	1.0023	1.0025	1.0022	1.0045
11	1.1022	1.1023	1.1027	1.1024	1.2152
12	1.2025	1.2029	1.2030	1.2028	1.4467
13	1.3028	1.3030	1.3030	1.3029	1.6975
14	1.4030	1.4030	1.4029	1.4029	1.9683

c. Table for velocity

#	Velocity 1(m/s)	Velocity 2(m/s)	Velocity 3(m/s)	Velocity average(m/s)
1	0.21	0.30	0.34	0.28
2	0.28	0.37	0.40	0.35
3	0.35	0.43	0.46	0.41
4	0.41	0.49	0.53	0.47
5	0.47	0.56	0.60	0.54
6	0.54	0.63	0.67	0.61
7	0.61	0.70	0.73	0.68
8	0.68	0.75	0.79	0.74
9	0.73	0.81	0.84	0.79
10	0.79	0.87	0.90	0.85
11	0.85	0.93	0.97	0.91
12	0.92	0.78	0.43	0.71
13	0.93	0.18	-0.19	0.30
14	0.31	-0.22	-0.20	-0.03


position x vs time t
time in seconds
position in metres
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.3029
1.2028
1.1024
1.0022
0.902
0.8018
0.7016
0.6014
0.5013
0.4011
0.3009
0.2008
0.1007


position vs time squared t2
time squared
position in metres
2.5
2
1.5
1
0.5
0
-0.5
0
0.2
0.4
0.6
0.8
1
1.2
1.9683
1.6975
1.4467
1.2152
1.0045
0.8136
0.6428
0.4922
0.3616
0.2513
0.1608
0.0905
0.0403
0.0101



d. Calculations

From graph x vs time squared

y_2=1.2152 y_1=1.0045

x_2=0.868 x_1=0.778

slope1=y_2-y_1/x_2-x_1

=1.2152-1.0045/0.868-0.778

=2.34

From the graph velocity vs time

y_2=1.1024 y_1=1.0022

x_2=0.97 x_1=0.90

slope2= y_2-y_1/x_2-x_1

=1.1024-1.0022/0.97-0.90

=1.4314

From above this means, acceleration from x-t^2 graph is 2.34m/s^2 and from v-t graph it is 1.4314m/s^2

3. At height 10 centimetres

a. Table for position

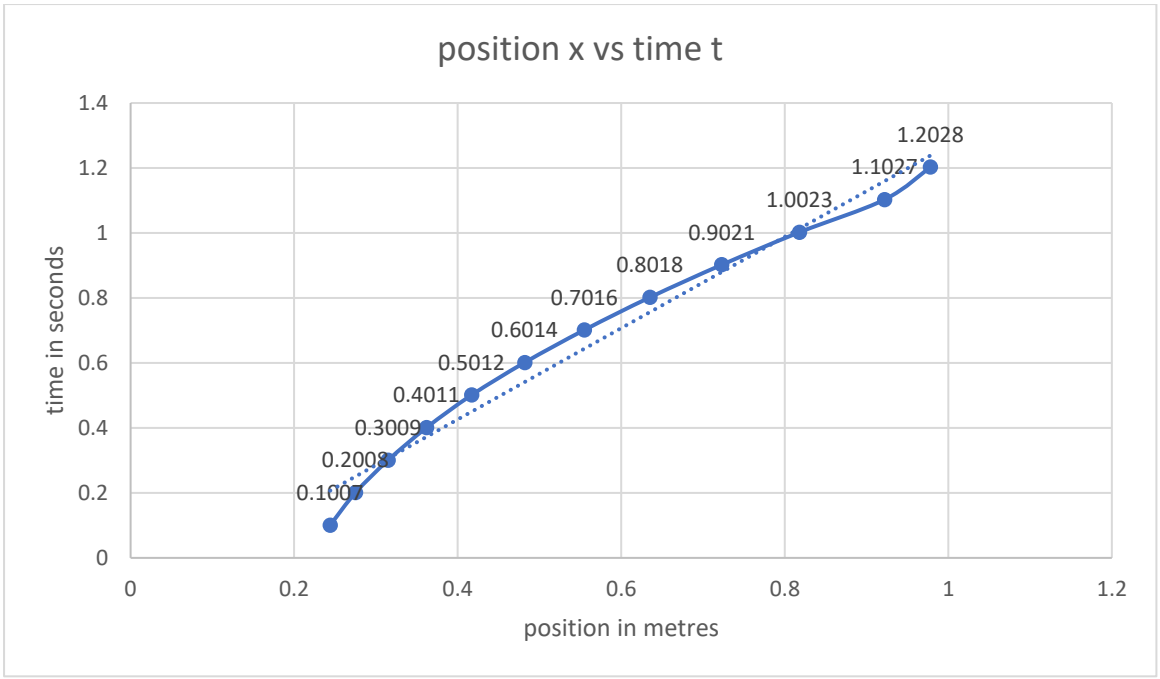
#	Position 1 (m)	Position 2 (m)	Position 3 (m)	Average position (m)
1	0.258	0.214	0.262	0.244
2	0.294	0.234	0.298	0.275
3	0.339	0.263	0.343	0.315
4	0.391	0.299	0.396	0.362
5	0.452	0.344	0.457	0.417
6	0.522	0.397	0.527	0.482
7	0.602	0.458	0.605	0.555
8	0.687	0.527	0.691	0.635
9	0.780	0.606	0.784	0.723
10	0.880	0.691	0.883	0.818
11	0.990	0.784	0.993	0.922
12	1.027	0.883	1.026	0.978

b. Table for time

#	Time 1(s)	Time 2 (s)	Time 3 (s)	Time avg(s)	Time avg squared(s^2)
1	0.1007	0.1006	0.1008	0.1007	0.0101
2	0.2009	0.2007	0.2009	0.2008	0.0403
3	0.3010	0.3008	0.3010	0.3009	0.0905
4	0.4011	0.4009	0.4012	0.4011	0.1608
5	0.5013	0.5010	0.5013	0.5012	0.2512
6	0.6015	0.6012	0.6015	0.6014	0.3616
7	0.7018	0.7013	0.7018	0.7016	0.4922
8	0.8020	0.8015	0.8020	0.8018	0.6428
9	0.9023	0.9018	0.9023	0.9021	0.8138
10	1.0026	1.0020	1.0026	1.0023	1.0046
11	1.1029	1.1023	1.1029	1.1027	1.2159
12	1.2030	1.2026	1.2030	1.2028	1.4467

c. Table for velocity

#	Velocity 1(m/s)	Velocity 2(m/s)	Velocity 3(m/s)	Velocity average(m/s)
1	0.32	0.15	0.32	0.26
2	0.40	0.24	0.41	0.35
3	0.49	0.33	0.49	0.43
4	0.57	0.41	0.57	0.51
5	0.65	0.49	0.65	0.59
6	0.75	0.57	0.74	0.68
7	0.83	0.65	0.82	0.76
8	0.89	0.74	0.89	0.84
9	0.96	0.82	0.96	0.91
10	1.05	0.89	1.04	0.99
11	0.73	0.96	0.71	0.80
12	0.14	1.04	0.12	0.43


position x vs time t
time in seconds
position in metres
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.2028
1.1027
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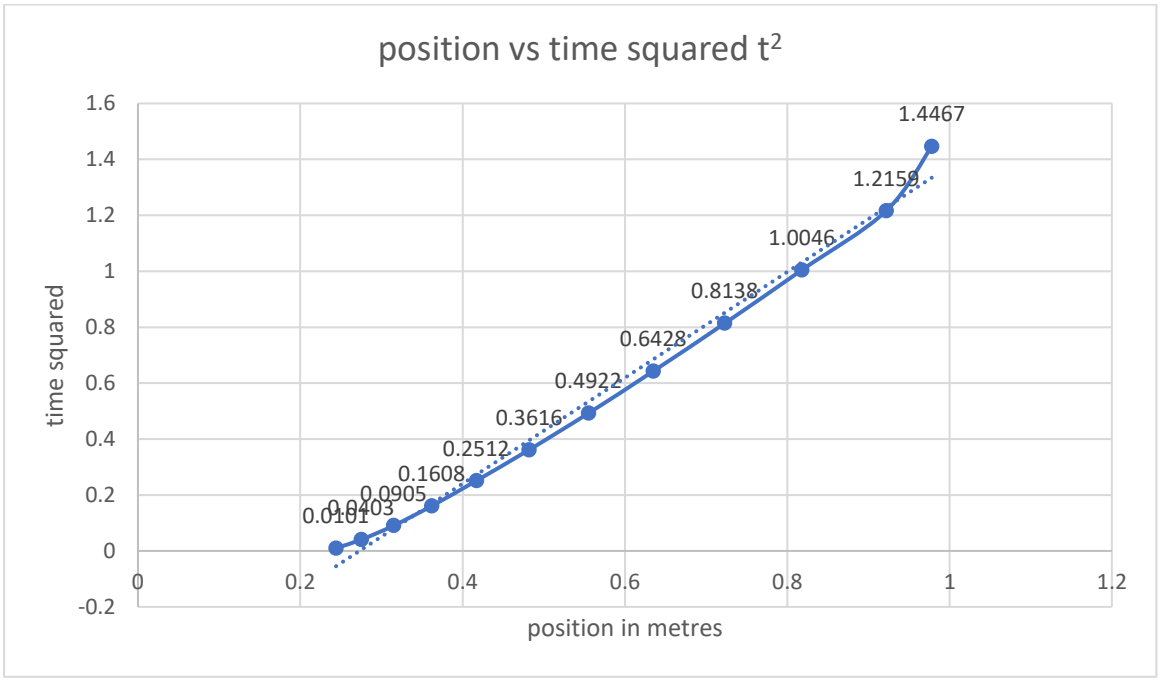
0.1007


position vs time squared t2
time squared
position in metres
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4467
1.2159
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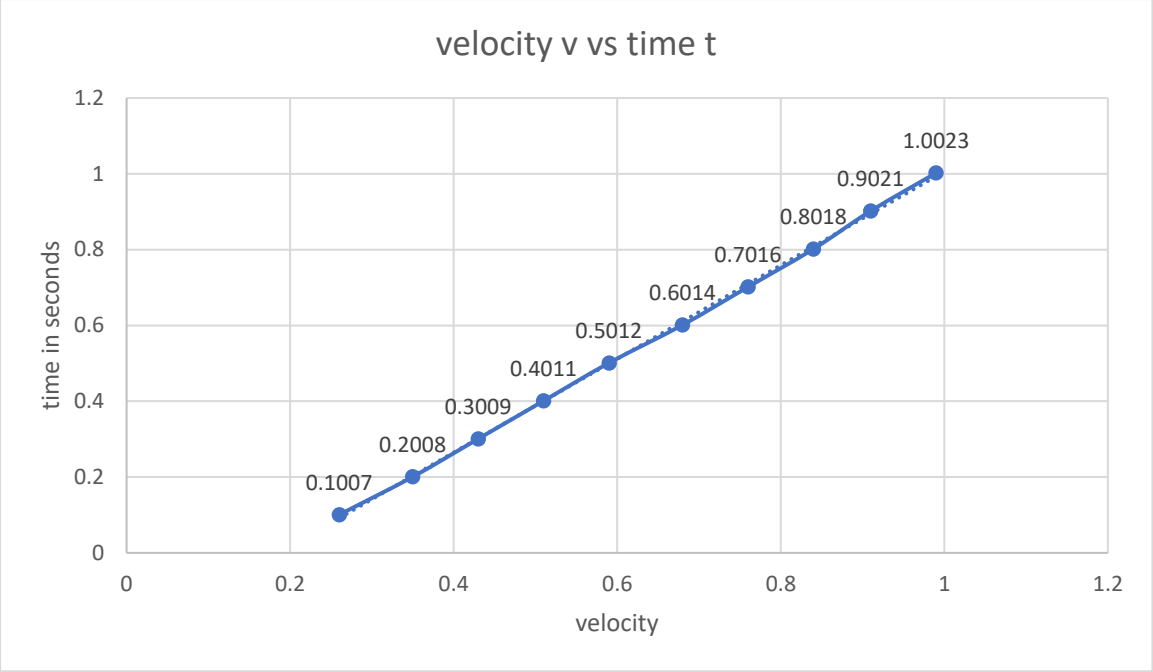
0.0101



d. Calculations

From graph x vs time squared

y_2=1.0046 y_1=0.8138

x_2=0.818 x_1=0.723

slope1=y_2-y_1/x_2-x_1

=1.0046-0.8138/0.818-0.723

=2.00

From the graph velocity vs time

y_2=1.0023 y_1=0.9021

x_2=0.99 x_1=0.91

slope2= y_2-y_1/x_2-x_1

=1.0023-0.9021/0.99-0.91

=1.2525

From above this means, acceleration from x-t^2 graph is 2.00m/s^2 and from v-t graph it is 1.2525m/s^2

4. Stopwatch timings and velocity from it

Total distance travelled is 0.85m

Height	time	Average time	velocity
5cm	T1-1.85 T2-2.09 T3-1.69	1.87	0.45
7.5cm	T1-1.50 T2-1.40 T3-1.37	1.42	0.59
10cm	T1-1.16 T2-1.25 T3-1.25	1.22	0.69

This means that as the height increases the average velocity also increases and the time taken to complete the track decreases.

5. Time at photo gate and maximum velocity

#	Velocity In Gate (m/s)	Time In Gate (s)
1	0.08 0.02	0.118756 0.405544
	0.08 0.01	0.118923 1.058764
	0.08 0.01	0.119314 0.828230
2	1.01 0.12	0.099466 0.819551
	1.00 0.16	0.099659 0.622566
	1.00 0.16	0.099545 0.627302
3	0.19 1.12	0.533062 0.089046
	0.51 1.11	0.197266 0.089746
	0.41 1.12	0.246810 0.089581

Discussions

From the first equation of kinematics, which is $v=v_0+at$

In this situation, v_0 is 0 because the cart is starting from the rest. This changes the equation to v=at.

For the slope of this equation, v/t=a

Here acceleration is the slope of the graph

Moreover, when using the second equation of motion, $x=x_0+v_0t+1/2at^2$

$x-x_0=1/2\ at^2$

neglecting v_0 because cart starts from 0

$x-x_0/t^2=a/2$

according to the above result, half of acceleration is the slope of the graph

furthermore, the graph between v and t is a straight line because the equation can be compared to y=mx+c and the graph between x and t^2 is parabolic, since the equation can be compared to $y^2=4ax$ which is the basic parabolic equation.

Conclusions

- The graph of x vs t^2 is parabolic in nature.
- The graph of v vs t is straight line in nature.
- The graph of x vs t is straight line in nature.
- The slope is found to be a/2(for x vs t^2) and a (for v vs t).
- As the height increases, the velocity also increases and time decreases to complete the track.

- The acceleration is kept constant throughout the experiment, otherwise the equations are not valid.
- The slope of the v vs t graph is a and x vs t^2 graph is a/2. This means that there exists a relation between the two slope of different graph and are linked by a or acceleration

References

- Deakin university, SEB101 lab manual 2019.
- Fundamentals of physics by Resnik, Halliday and Walker, (10^{th} edition)
  Chapter 2