Physics 2211 - Lab 1

Constant Velocity Motion

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Outline

1. Introduction
   - Aim of the experiment
2. Prerequisites
   - Newton’s First Law
   - Initial conditions, system and surroundings
3. Experiment
   - Observation using Video
   - Computational Model
4. Conclusion

Outline

Aim

Purpose of this lab assignment

- Observe the motion of some object that is moving at the same speed without changing direction
- Analyzing the motion using software tools (Tracker) and capturing the object's positions at uniform time intervals.
- Creating a computational model using VPython to represent and predict motion in this situation, and compare it with actual data from Tracker.

Outline

Newton's First Law

Qualitative analysis of motion

"Every body persists in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by force impressed."

Newton's Second Law

Quantitative analysis of motion

"The net force acting on a body is defined as the change in its momentum per unit time."

$$\vec{F}_{net} = \frac{\mathrm{d}\vec{p}}{\mathrm{d}t} \tag{1}$$

In most daily life scenarios, mass doesn't change with respect to time, hence this equation is better known as:

$$\vec{F}_{net} = m \cdot \vec{a}$$

where,

- $\vec{F}_{net}$ = Net force acting on a body
- m = Mass of the body
- $\vec{a} = \frac{\mathrm{d}\vec{v}}{\mathrm{d}t} = \frac{\mathrm{d}^2\vec{r}}{\mathrm{d}t^2}$ = Net acceleration on body
- $\Delta\vec{p} = m \times \Delta\vec{v}$ = Change in momentum

Initial conditions

- $\vec{r} = \vec{0}$, where $\vec{r}$ stands for position vector
- $\vec{F}_{net} = \vec{0}$
- $\vec{v}_i \neq \vec{0}$, we have to calculate this!

System and surroundings

- **System:** Aerosol can (hereafter referred to as ‘object’)
- **Surroundings:** Everything else (table, air, etc.)

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Analysis of Video

Getting displacement at discrete time intervals using Tracker

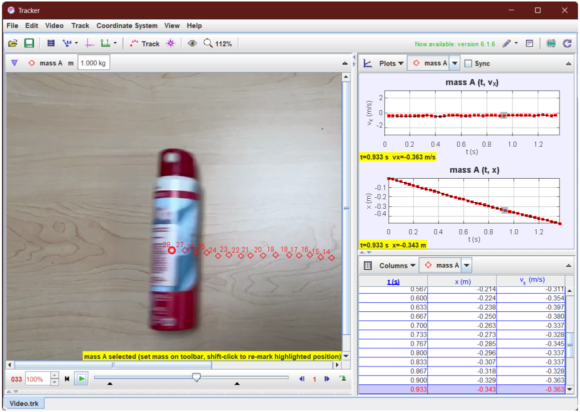

Figure 1: Using Tracker® to analyze the motion of the object.

Calculating Velocity

Time t (s)	X-Position r_x (m)
0.00×10^{0}	-2.88×10^{-3}
3.33×10^{-2}	-1.32×10^{-2}
6.67×10^{-2}	-2.59×10^{-2}
1.00×10^{-1}	-3.86×10^{-2}
1.33×10^{-1}	-5.18×10^{-2}
$\vdots$	$\vdots$

- $$\vec{v}_{avg} = \frac{\vec{r}_2 - \vec{r}_1}{t_2 - t_1}$$
- The average velocity of the first two rows is[a]: $\vec{v}_{avg} = \frac{-1.32\times10^{-2}\hat{i}\ \mathrm{m}-(-2.88\times10^{-3}\hat{i}\ \mathrm{m})}{3.33\times10^{-2}\ \mathrm{s}-0} = -3.11 \times 10^{-1}\ \mathrm{ms}^{-1}$

[a] The i-j-k hat notation for vectors has been used due to paucity of space.

Calculating Velocity

- Repeating this step multiple times, we can get the average velocity for each interval
- Ideally, the average velocity for each interval should be constant, but due to various factors such as air resistance , friction on the surface, etc, the velocity is not constant.
- Hence, we average the velocities of these small steps to get an accurate reading.

	A	B	C	D	E	F
1		mass_A				
2	t	x	V_x			
3	0.00E+00	-2.88E-03				
4	3.33E-02	-1.32E-02	-3.11E-01			
5	6.67E-02	-2.59E-02	-3.80E-01		Avg_vel	-0.34753
6	1.00E-01	-3.86E-02	-3.80E-01			
7	1.33E-01	-5.18E-02	-3.97E-01			
8	1.67E-01	-6.56E-02	-4.15E-01			
9	2.00E-01	-7.77E-02	-3.63E-01			
10	2.33E-01	-9.21E-02	-4.32E-01			
11	2.67E-01	-1.05E-01	-3.97E-01			
12	3.00E-01	-1.16E-01	-3.28E-01			
13	3.33E-01	-1.28E-01	-3.63E-01			
14	3.67E-01	-1.38E-01	-2.76E-01			
15	4.00E-01	-1.51E-01	-4.15E-01			
16	4.33E-01	-1.66E-01	-4.49E-01			
17	4.67E-01	-1.81E-01	-4.49E-01			
18	5.00E-01	-1.92E-01	-3.28E-01			
19	5.33E-01	-2.03E-01	-3.28E-01			
20	5.67E-01	-2.14E-01	-3.28E-01			
21	6.00E-01	-2.24E-01	-2.94E-01			
22	6.33E-01	-2.38E-01	-4.15E-01			
23	6.67E-01	-2.50E-01	-3.80E-01			

Figure 2: Using Excel to calculate average velocity

Data

Data needed for simulation

- Velocity of object at given instant $= -0.34753$ ms^{-1}
- Total time $= 1.37$s
- Initial position $= \vec{0}$

Code

Simulating the constant velocity

```
ball = sphere(color=color.blue, radius=0.22)
trail = curve(color=color.green, radius=0.02)
origin = sphere(pos=vector(0,0,0),
 ↪  color=color.yellow, radius=0.04)
plot = graph(title="Position vs Time",
 ↪  xtitle="Time (s)", ytitle="Position (m)")
poscurve = gcurve(color=color.green, width=4)
plot = graph(title="Velocity vs Time",
 ↪  xtitle="Time (s)", ytitle="Velocity
 ↪  (m/s)")
velcurve = gcurve(color=color.green, width=4)
ball.m = 1
ball.pos = vector(0,0,0)
ball.vel = vector(-0.34753,0,0)
```

Code

Continued from previous

```
t = 0
deltat = 0.001
while t < 1.366667:
    rate(1000)
    Fnet = vector(1,1,1)
    ball.vel = ball.vel + vector(0,0,0)
    ball.pos = ball.pos + ball.vel*deltat
    t = t + deltat
    trail.append(pos=ball.pos)
    poscurve.plot(t,ball.pos.x)
    velcurve.plot(t,ball.vel.x)
    print(t,ball.pos.x)
print("All done!")
```

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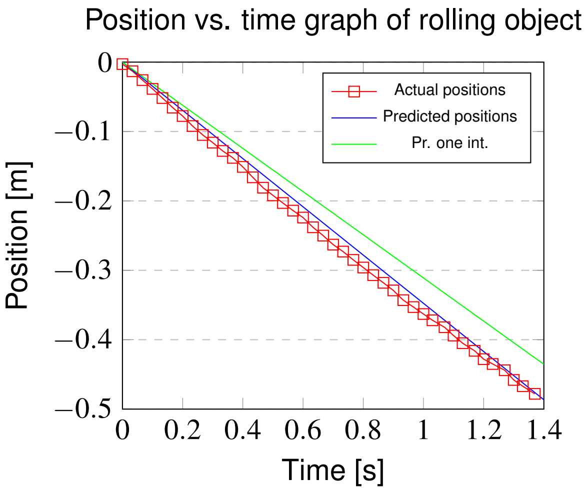
Predicted velocity vs. real velocity



What If

...orientation of the axes were flipped?

The position and velocity would be in the opposite direction! Put in physics terms, the *axes* component of velocity and the position vectors will now have to be multiplied by -1.

What does it mean?

Is it possible for to say how many forces are added together to give zero net force?

- **TL;DR** No.
- This is because we can go down various levels of “forces”. For example, if we considered the atomic interaction forces, there would be MILLIONS of forces, and there is no possible way to count that accurately.
- Also, in the real case, net force isn’t zero! This is due to external forces like friction.