Recitation Session 1

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My Background

- My name is Achint Kumar. I am a 5th year PhD candidate in Physics Department.
- I have an undergraduate degree in physics and electrical engineering
- My research is in machine learning and computational neuroscience. I am advised by Prof.John Pearson(ECE) and Prof. Richard Mooney(Neurobiology)
- In my research, I use deep learning to understand how the brain works.

Structure of the Discussion-1 (11:00am-12:15pm)

- 20-25 minutes: Overview of lecture, introduce new concepts
- Remaining time: Solving discussion problems

Structure of the Discussion-2 (1:15pm-3:15pm)

- Solving problems
- Last 20 minutes: Quiz. With prior permission you can get extra time.

Please feel free to contact me at: achint.kumar@duke.edu.

The slides will be available on my website:
achintzeus1994.github.io

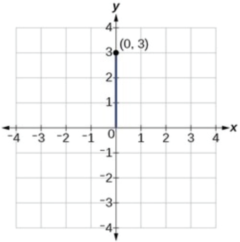
Today's discussion

Topics we will cover today:

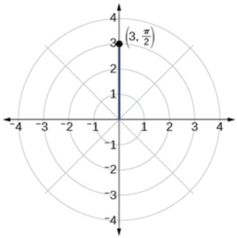
- Position, x
- Velocity, v
- Acceleration, a
- Kinematics equation for constant acceleration 1D motion
- Projectile Motion

How to measure position?

1. Choose a reference frame (convenient vantage point). It could be anything, say you, tree, moving car, etc. Assign this point to be the origin of your coordinate system.
2. Set up your coordinate system: Cartesian or Polar coordinates. It can point whichever way you like.
3. Use meter stick or protractor to find the coordinates ((x,y) or (r, θ)) of the point of interest.



Coordinate Grid



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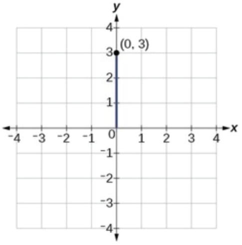

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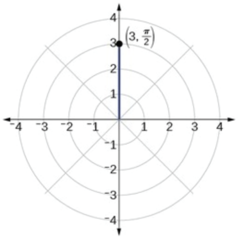

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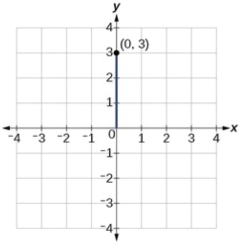

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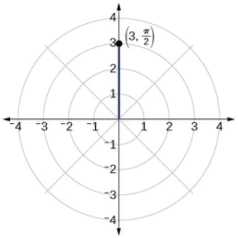

Polar Grid

Displacement versus Distance

Displacement

- Displacement is the change in position of the object.
- If the object returns to original position after motion, displacement is zero
- It is vector quantity which can be positive, negative or zero

Distance

- Distance is total length travelled by an object.
- If the object returns to original position after motion, distance is not is zero
- It is a scalar quantity which is always positive

- Scalars can be negative also. It just so happens that distance and speed are always positive
- I throw.a ball at an angle, when it reaches the ground again is displacement zero? What about distance?

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Life lesson-1

Whenever you encounter a new problem, analyze and understand of the simplest case before tackling the harder cases.
Examples:

1. Analyze 1 dimensional motion before 2 dimensional motion
2. Understand object at rest before trying to understand objects which are moving (Done!)
3. Understand objects moving with constant velocity motion before accelerated motion.

Velocity in 1D

Velocity is rate of change of position.

$$v = \frac{dx}{dt}$$

Note:

- Velocity can be positive or negative. Positive indicates increasing position, negative indicates decreasing position wrt the coordinate system
- It is a vector quantity
- In constant velocity motion, we can write $\Delta x = v\Delta t$

Problem 1

Problem 1

Two trains are on the same track a distance D apart heading towards one another, each at a speed of v. A fly starting out at the front of one train, flies towards the other at a speed of u. Upon reaching the other train, the fly turns around and continues towards the first train. What distance does the fly travel before getting squashed in the collision of the two trains?

Hint

- Use Life-lesson 1: Make the problem simpler. One way to do it is to make one of the trains be at rest. Can you solve the problem in this case?

Problem 1: Solution

Time before the trains collide $=\frac{D}{2v}$.
Distance travelled by bee in that time is, L$= u\Delta t = \frac{Du}{2v}$

Acceleration

Acceleration is the rate of change of velocity.

$$a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$$

- Acceleration can be positive or negative. It is a vector quantity
- An alternate, useful form of acceleration using chain rule gives, $a = v\frac{dv}{dx}$

Kinematics equations for uniformly accelerated motion

We have,

$$a = \frac{dv}{dt}$$

Integrating assuming constant acceleration gives,

$$v = u + at \tag{1}$$

Integrating again gives,

$$x = x_0 + ut + \frac{1}{2}at^2 \tag{2}$$

Integrating $a = v\frac{dv}{dx}$, we get,

$$v^2 = u^2 + 2ax \tag{3}$$

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Problem 2

Problem 2

A space gun can provide a constant acceleration $a = 5g$ over a distance L. If we want the space gun to reach the escape velocity of Earth (11.2 km/s which you can approximate as 11 km/s), what should the minimum length L of space gun be to achieve that speed? How long will it take for a particle to achieve the escape velocity starting from rest ?

Problem 2 Solution

Use,

$$v^2 = u^2 + 2ax$$

This gives,

$$L = \frac{v^2}{2a} = \frac{(11.2 * 1000)^2}{2 * 5g} = 1254,400 km$$

To calculate time use,

$$v = u + at$$

So,

$$T = \frac{11.2 * 1000}{5 * 10} = 224 \,\mathrm{sec} = 3 \mathrm{min}\, 44 \,\mathrm{sec}$$

Navigation in brain