LU 9.13. Motion and graphs

Introduction

Moving objects and people around us are among the most common sights for us in our daily life. In Physics, motion is understood in terms of two basic intuitive notions --- distance and time. The motion of an object is described and explained by quantifying how fast or slowly the object covers a certain distance, and even how this rate of motion is changing with time.

On 16th August 2009, at the 12th IAAF World Championships in Athletics, Berlin (Germany), Jamaican sprinter Usain Bolt set a new world record in 100-meter dash. He finished the race in 9.58 seconds breaking his own record of 9.69 seconds which he had set one year ago at the Beijing Olympics.

Video of the Usain Bolt's race is available here.
https://youtube.com/clip/Ugkxj3z_7aeZbBsn8Gdj6gWLtHhjyYJsTzKp

Watch the video. Usain Bolt is the fourth athlete from right in a yellow t-shirt (he is in the front in the image below). There is a timer running on the video. Try to answer the following:

Q1. From start to finish, does his speed remain same throughout the race or it increases with time?

_____

_____

Image 1: *Jamaican sprinter Usain Bolt leading the race.*

Note: If you don't have laptop or PC, you can go ahead with other tasks, this will not hamper other tasks.

Task 1: Analyzing a walk

Shabana is moving on a straight flat track. The following picture identifies six different locations (A, B, C, D, E, and F) of Shabana at different distances on the track.

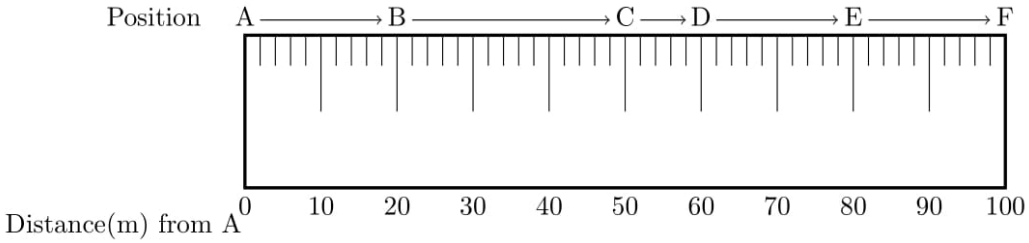


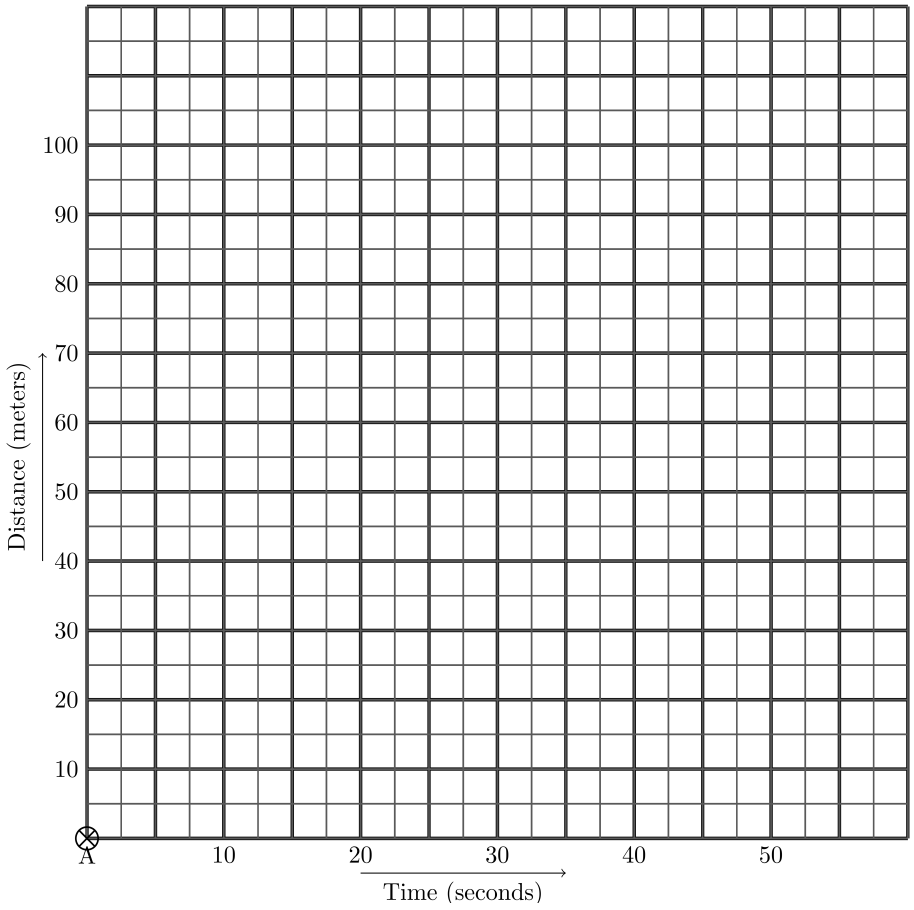
Image 2: *Positions of Shabana on a track.*

Table below shows the times at which positions of Shabana is indicated on the track. In the 3rd column write the corresponding distances of Shabana from A.

Position	Time (seconds)	Distance (metre)
A	0	
B	10	
C	20	
D	30	
E	40	
F	50	

Table 1: *Table of time for various positions of Shabana on a track.*

Represent the motion of Shabana as a distance v/s time graph by marking its distance from the starting point (A). Use the values from the table above to plot at the remaining locations (B, C, D, E and F). Location A is already indicated in the graph by ⊗. Join the successive points by straight lines.



Graph 1: *Shabana's distance v/s time graph.*

By looking at the nature of the graph, during which interval, Shabana most likely is

i) the fastest: _____

ii) the slowest: _____

iii) faster than the previous interval: _____

While we do not know the details of motion of Shabana between the given points, we can still learn a lot about the overall motion of Shabana by calculating its average speed between each consecutive pair of points.

Calculate the average speed in each interval between successive points and fill the below-given table. To help you, calculation of average speed between A-B is given in the third column.

Discuss with your friends the distinction between instantaneous speed and average speed. Here we can get only the average speed and not the instantaneous speed.

Time interval (seconds)	Change in position	Average speed (metre/second)
0-10	(A-B)	(20-0)/(10-0)=2
10-20	(B-C)	
20-30	(C-D)	
30-40	(D-E)	
40-50	(E-F)	
0-20	(A-C)	
0-50	(A-F)	

Table 2: Calculation of average speed

During which time interval(s) is its average speed

(a) Maximum?_____

(b) Minimum?_____

(c) greater than what it was in the previous time interval? _____

Kindly notice that in the previous part, you have drawn the same conclusions without calculating the average speeds.

Task 2: Analyzing Bolt's run

In this exercise, we will try to analyze Bolt's 2009 run (refer Introduction for the video).

During the race, a camera was running parallel to Bolt and recorded time every 10 meters. The time record at every 10 m distance is given below.

Distance (m)	Time (s)
0	0
10	1.89
20	2.88
30	3.78
40	4.64
50	5.47
60	6.29
70	7.10

80	7.92
90	8.75
100	9.58

Table 3: Usain Bolt's running data

Four different graphs are given below. The scales and labels of the y-axis are not given.

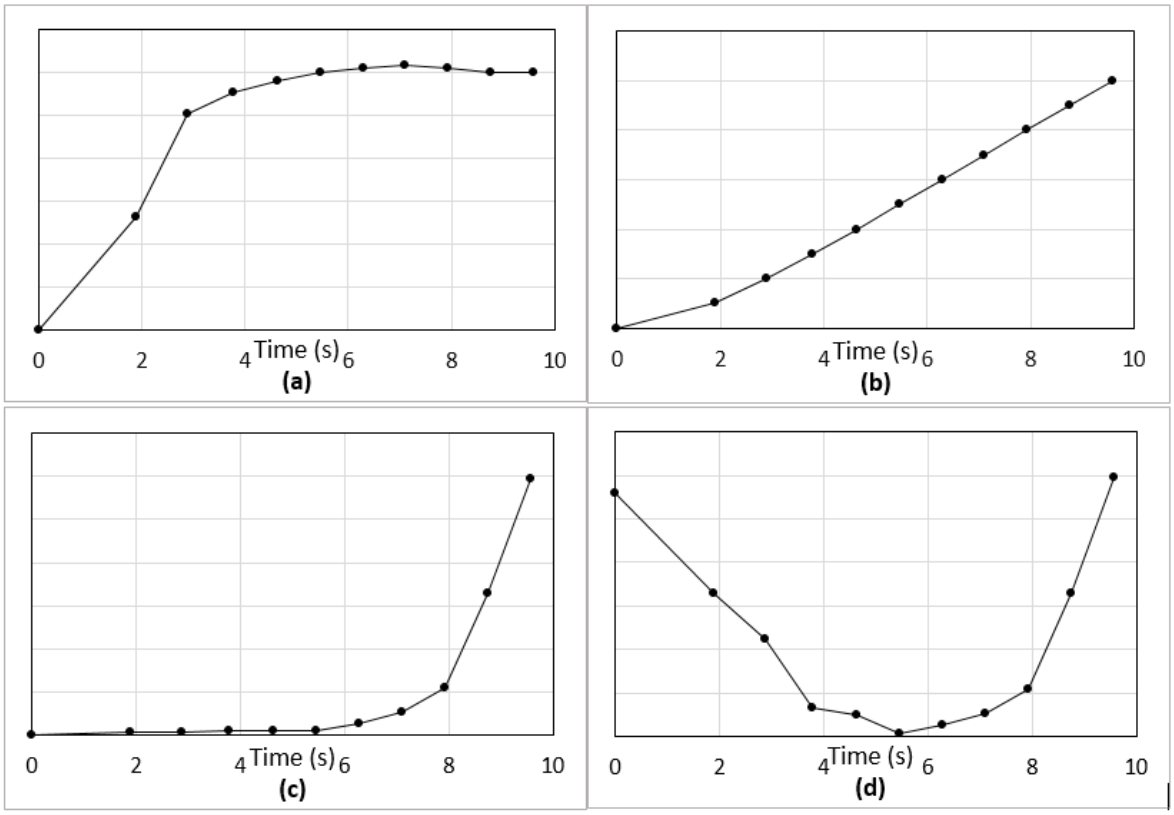


Figure 1: Graphs with y-axis missing

Q2.1. Identify which graph is distance versus time for the Usain bolt's run.

_____

After Identifying distance vs time graph, from the remaining three graphs

Q2.2. Identify which graph is speed versus time.

_____

The time rate of change of speed is known as acceleration.

Q2.3. From identified speed vs time graph, find in which time interval does he accelerate the most?

_____

Task 3: Plotting your friends run

This activity requires minimum 12 students. Gather your friends and come to the playground. One of you has to run a 100-meter race and the rest of the friends will record the timing at every 10 meters. In other words, we have to record your running timing and produce a data table similar to Bolt's performance shown in Part 2(a). Ideally, collect the data for two runners. Runners may run fast or slow depending on their capacity.

One of the method to conduct this is as follows:

1) Identify a 100/50-meter flat track.

2) Starting from 0 meters, ask your friends with a stopwatch to stand every 10 meters till 100 meters. You will need 11 students for this. Set stopwatches in counter mode. We will call these students *Markers.* You can also use stopwatch mode on a mobile phone.
3) Decide a convenient method to operate/synchronize clocks. Make the students aware of the least count of the clock. Use minimum possible least count.
4) Draw a line on the track at equal intervals each, say 5/10m each and markers should stand at the intervals. One of you can play the role of Usain Bolt. We will call her/him *Runner.* As soon as the runner starts the race all the *markers* should start their stopwatches. The *Markers* have to stop their respective stopwatches when the *Runner* crosses their interval line.
5) After the race, record the timing from each stopwatch in the following table.
6) Calculate the speed for each interval.

For more than 1 runners, you may use the extra tables given in the appendix at the end of this unit.

Distance (m)	Time (s)	Distance interval(m)	Time interval(s)	Average speed (m/s)
0	0	-	-	0

Table 4: *Students' running data for speed*

Plot speed vs time for the runner and compare with Usain Bolt's performance plot.

Answer the following questions.

Q1. Is the shape of your graph similar to his performance? If not, then what are major qualitative differences?

_____

_____

Q2. What is the maximum speed that the *runner* has achieved and during which time interval?

_____

Q3. Is the *runner's* speed continuously increasing during the race?

_____

Q4. Can you now calculate the acceleration of the runner at different times and enter the values in the table on the previous page?

Average speed (m/s)	Time (s)	Time interval(s)	Acceleration (m/s^2)
0	0	-	0

Table 5: Students' running data for accleration

Q5. Can you identify the differences between the maximum acceleration of your friend and that of Usain Bolt?

Task 4: (Possible extension) Perimeter of your school

Without using any meter tape, estimate the approximate total perimeter of your school playground. You can only use a stopwatch and a standard 30cm ruler for this activity. Briefly describe your measurement technique.

Measurement technique:

Draw the shape of the playground:

Total perimeter:

Appendix: Table for recording runner's data

Distance (m)	Time (s)	Distance interval(m)	Time interval(s)	Average speed (m/s)
0	0	-	-	0

Distance (m)	Time (s)	Distance interval(m)	Time interval(s)	Average speed (m/s)
0	0	-	-	0