Solution : Cricket Problem – What's the Result !?

Cricket Problem

Part (a)-

Let's observe this part carefully. The question asks us the importance of the 3 portions in the graph of the maximum effort chart.

What exactly is maximum effort chart of a Player ?

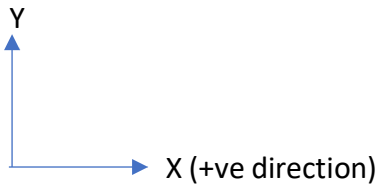
- Consider a player 'X'. Now this player X is asked to perform a Task. The Task is to complete running 3 runs on the pitch. During the task is being done, the speed of the player is being tracked w.r.t time. The player is asked to run at its maximum ability.

- After we get the data, we draw the **velocity-time graph** and this is what we call as the maximum effort chart.

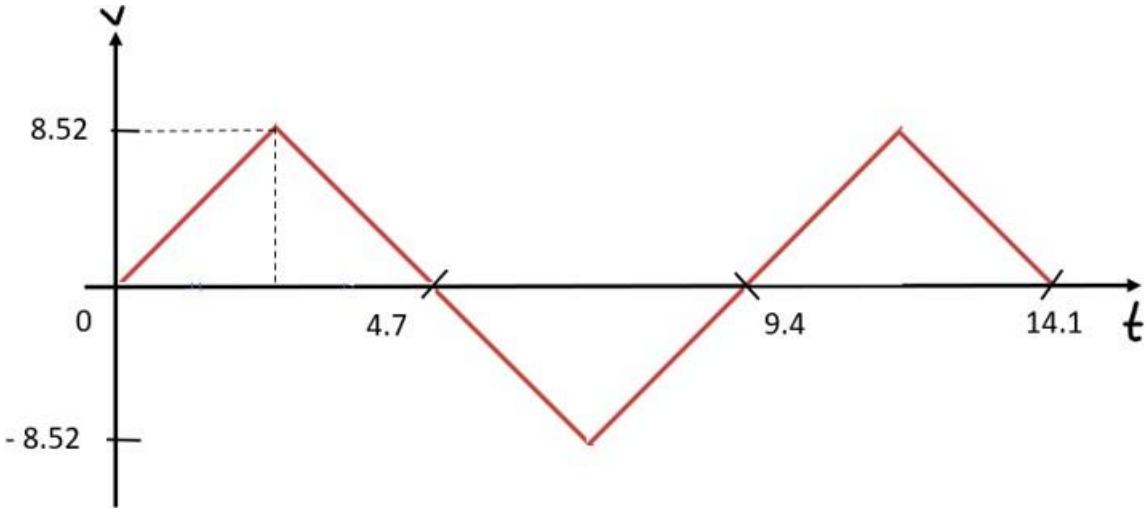
This observation that, those 3 portions correspond to the 3 runs was very much essential to solve the part (b) as well. But, how exactly can we verify this fact, let's see that on next page…

Let us first analyze the maximum effort chart of Non - Striker : (it's much easier)

(For striker*)



- *Striker's maximum effort chart* : (v in m/s and t in sec)



Region t = 0 to t = 4.7 s : ---- (1)

- The batsman just starts to run with initial velocity = 0, starts running and while running, he reaches a maximum speed of 8.52 sec.

- After this, he starts to slow down since he has to stop momentarily at non-striker's end to complete the run.

- And finally at t=4.7s , he completes his 1st run across the pitch.

Also to verify, we can calculate the area under this graph. It's basically a triangle :

$$Area = \frac{1}{2} * 8.52 * 4.7 = 20.022 \approx 20m$$

Now, 20m is nothing but the length of the pitch. So, we can say that the striker covers the first run in 4.7 sec. (Displacement = +20m)

Region t = 4.7 to t = 9.4 s ----- (2)

- Here, the striker starts to run for the 2nd run and this time it's the same thing happening again but in the opposite direction.

- The striker starts to run for second run at t=4.7s, reaches a maximum velocity of -8.52 m/s , starts to slow down and then stops at the striker's end again momentarily at t=9.4s

Again, you can verify the same, since the dimensions of the triangle (in graph) remain the same. The difference is that, we get the displacement now as **'-20m'** since he ran 20m in -ve direction.

From discussions (1) and (2),

The net displacement of striker at the end of 9.4sec is zero since he is at the same position where he started running at t=0 (the striker's end)

Region t = 9.4 to t = 14.1 s

Same thing happens as mentioned in (1) and finally 3 runs are completed and the striker (originally) is now at non-striker's end. Hence the net displacement will be = +20-20+20 = 20 m

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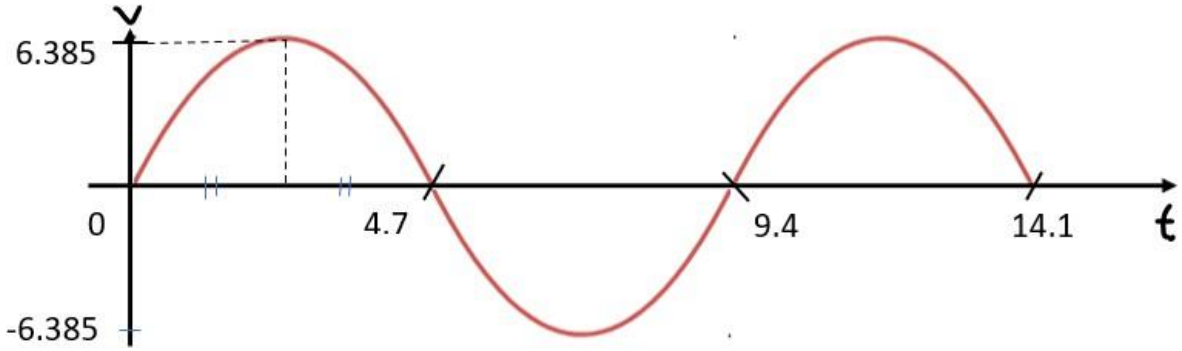
So at maximum potential, the batsman at striker's end makes 1 run in 4.7s, 2 runs in 9.4s and 3 runs in total time of 14.1 sec.

- Non-Striker maximum effort chart

  The same thing applies here as well. The difference is just between the nature of the graphs. The striker's chart is linear in nature while the non-striker has parabolic nature of graph



  Here, as well if you calculate the area under the curve for the region t = 0 to 4.7s , you get an approximate value of 20m.

  Hence, both striker and non-striker are able to make 3 runs within 14.1 sec

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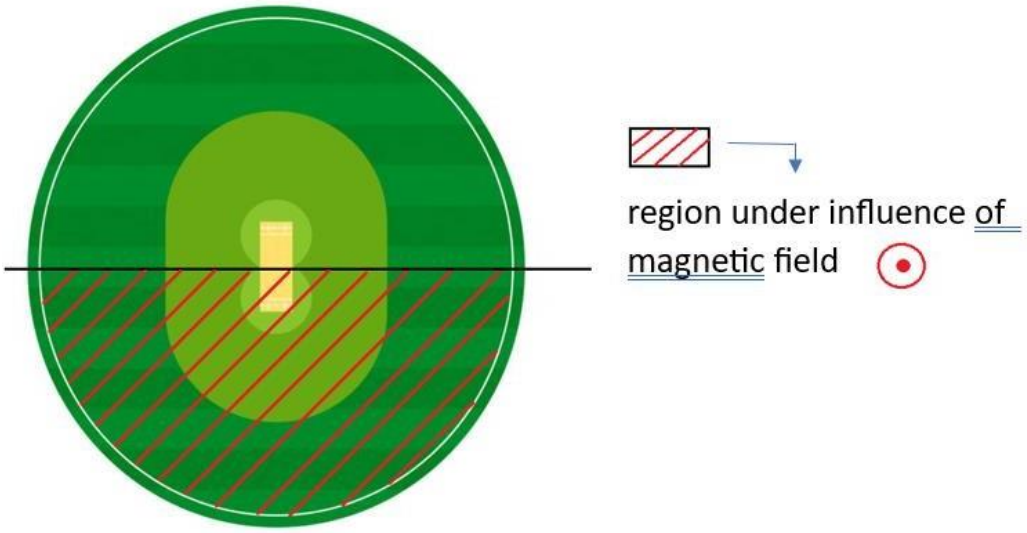
Part-(b) :

Now, something happened on the ground. Actually, a magnetic field of '0.54 T' was set up on the ground in the region as shown:



Now, when the bowler pitches the ball, the ball straight away goes as a toe-crushing yorker falling 'just infront of the stumps'. Replying to which, the batsman flicks the ball as shown below :

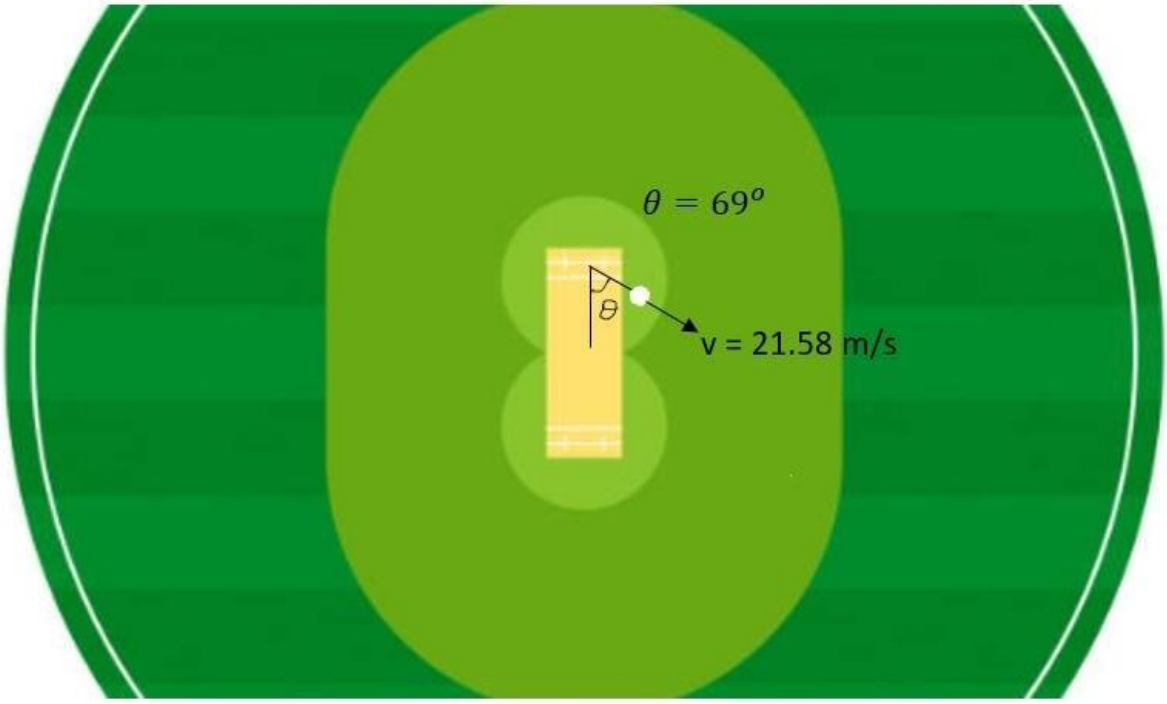
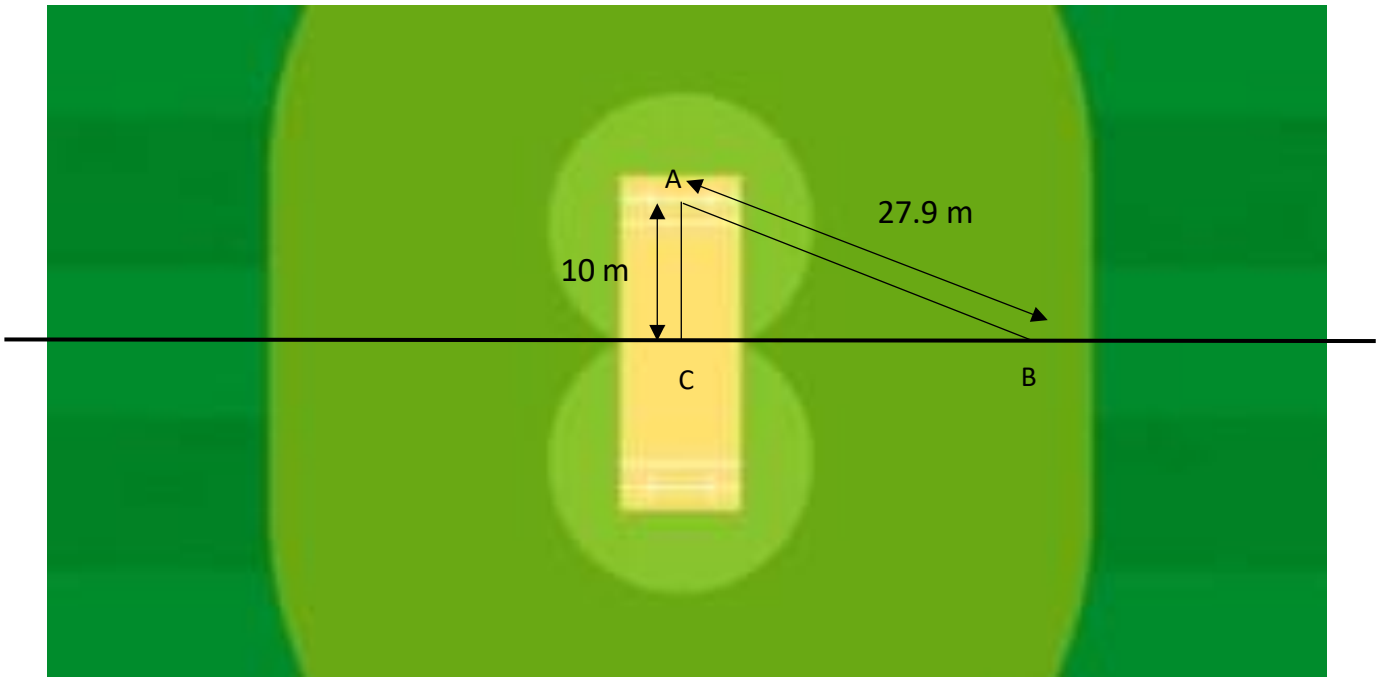


Fig. Last ball Situation

There is no friction between the surfaces. Hence, the ball will continue moving with the same speed atleast before entering the magnetic field region.



(Above lengths are found out by simple trigonometry)

Now, the time taken by ball to go from A to B is ' t_{AB}' (say)

$$t_{AB} = \frac{d}{v} = \frac{27.9}{21.58} = 1.29\ s$$

At point B, it enters the magnetic field of 0.54 T with a velocity of 21.58 m/s. Also we know that the ball has a charge 'q' of 164mC and has a mass 'm' of 160g

Note that, if the ball touches the boundary, it's game over for MI, hence to predict the result, we need to check whether the ball touched the boundary or not!!

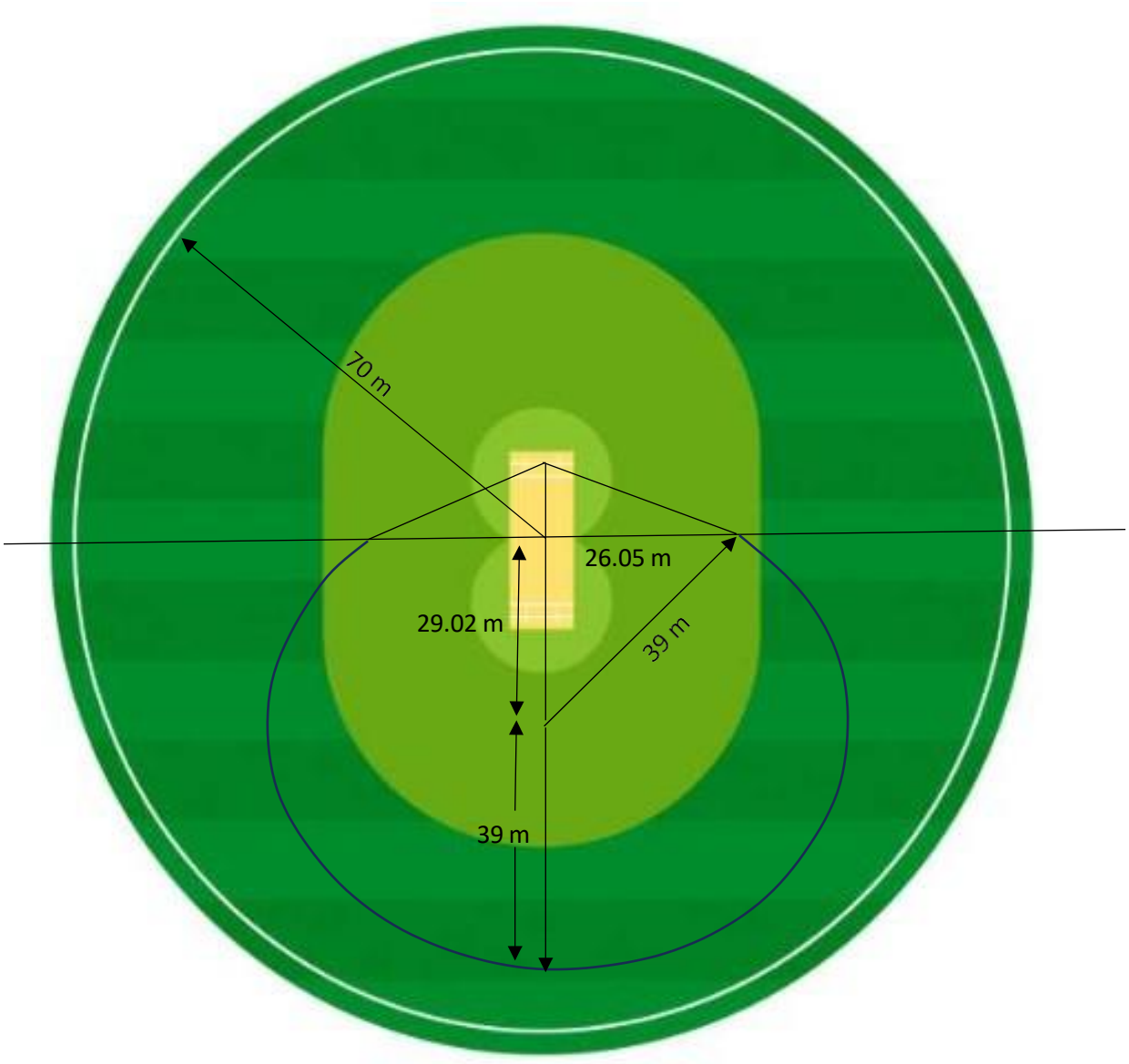
So, we find the radius of the circular path (R) which the ball covers in the region of magnetic field.

$$R = \frac{mv}{qB}$$

$$R = \frac{(0.16\ kg) * (21.58\ m/s)}{(0.164\ C) * (0.54\ T)}$$

$$R = 38.99 \approx 39\ m$$

If we look at the ground now, it will look like this:



(All the calculations are done using basic trigonometry and Pythagoras theorem)

- We can see that, from the centre of the ground 'C', the ball can only go max upto (39+29.02 =) 68.02 m.

- But the boundary is 70m from 'C'. Hence, we can conclude that GT cannot win the match but still they have a chance to **TIE** the match

- The ball starts to return back to D and we can predict that it is going to hit the stumps again at point A.

- So, in order to decide the result, we need to consider the following cases: (Let time taken to complete 3 runs be t_{3runs} and time taken by ball to cover the path A-B-C-D-A be t_{ABPDA})

  1. If $t_{3runs} > t_{ABPDA}$: then, MI wins the match !!

  2. If $t_{3runs} < t_{ABPDA}$: then, match is drawn MI=GT !!

  Since, Last ball situation was :

From the Part(a) analysis, we know that,

$$t_{3runs} = 14.1\ sec$$

We need to calculate, t_{ABPDA}

Since the path is symmetrical,

$$t_{AB} = t_{DA} = 1.29\ s$$

Let's calculate t_{BPD},

This is nothing but, the time taken by charge in magnetic field,

For 1 full circle, angle subtended at centre is 2π, and the time taken by charge is $\frac{2\pi m}{qB}$

Angle subtended at centre 'C' (rad)		Time taken
2π	→	$\frac{2\pi m}{qB}$
1	→	$\frac{m}{qB}$
$2.4\ (138^o)$	→	$\frac{2.4m}{qB}$

$$t_{BPD} = \frac{2.4 * 0.16}{0.164 * 0.54} = 4.34\ s$$

Therefore,

$$t_{ABPDA} = t_{AB} + t_{BPD} + t_{DA} = 6.92\ s < 14.1\text{s}$$

This implies that the ball hits the stumps before the batsmen could complete 3 runs.

Therefore, we can declare the result as :

There's a lot to learn !

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Important Highlights in the Question

What's the result !?

Cricket Problem

Commentary: Oh! we are witnessing the most exciting final ever. Just look at the score board mate! The crowd is going crazyyy here at the Wankhede stadium. For now, We are having some discussion going on between captain and umpires and seems like they have been given a new ball for the last ball of the match.

Scoreboard Situation

Commentary: Till the game resumes back, we show you the stats of the players as well as the info of the Wankhede stadium.

- **Striker :**
  - **Age : 26**
  - **Right handed batsman**
  - **Average : 25.5**
  - **Highest : 67(36)**
  - **Maximum effort chart: ('v' in m/s and 't' in s)**
    Nature of graph : Straight line

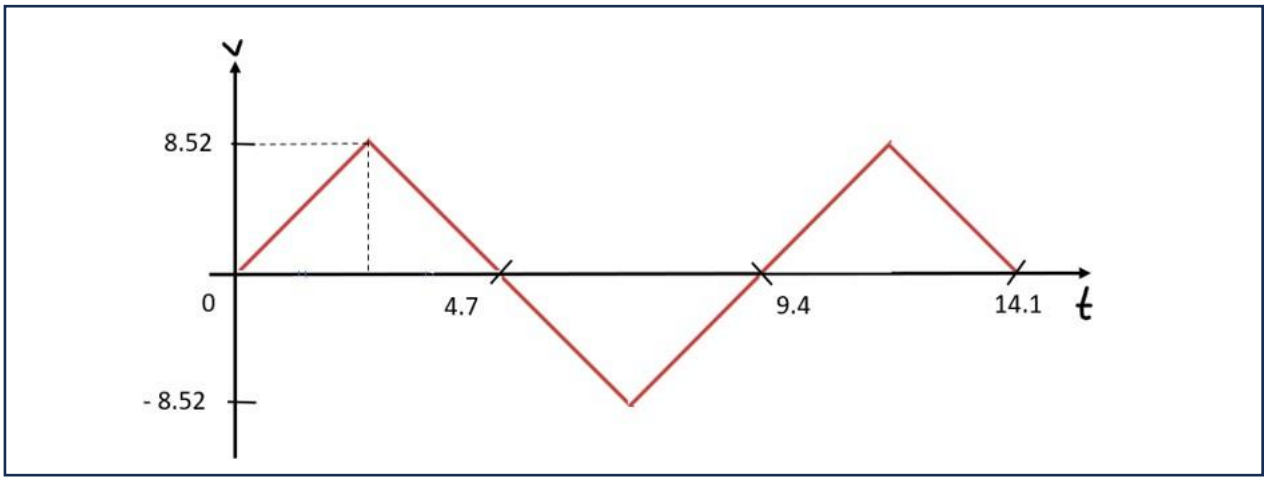

Fig. Maximum effort chart for Striker

- **Non-Striker :**
  - **Age : 27**
  - **Right handed batsman**
  - **Average : 23.2**
  - **Highest : 56(23)***
  - **Maximum effort chart: ('v' in m/s and 't' in s)**
    It's a curve of parabolas
    For $0 \leq x \leq 4.7$, $(y = ax^2 - 4.7ax)$ with $a = -1.156$

(This tells how a player runs between the wickets when he performs at his maximum potential and it's a pre-recorded data)

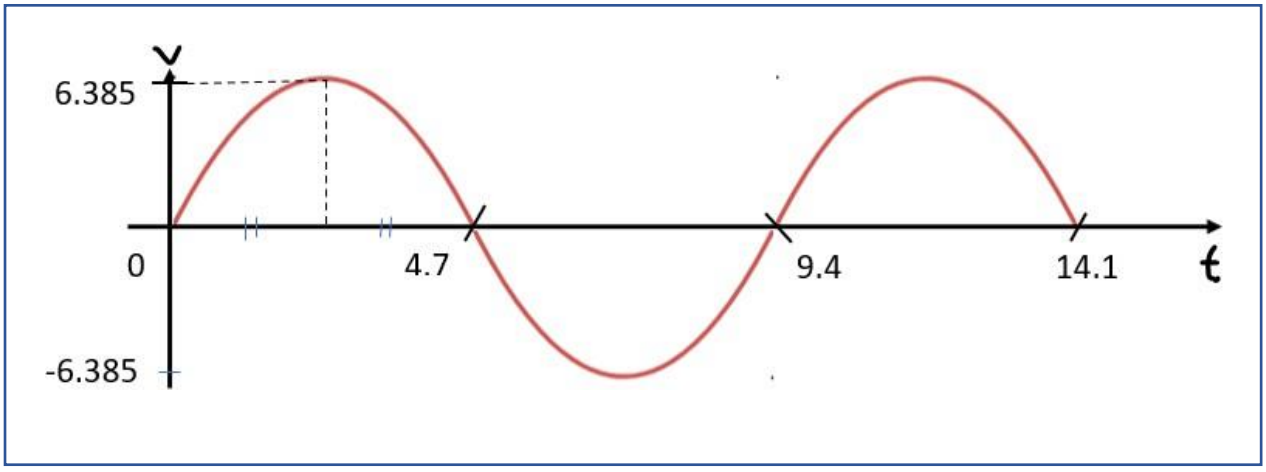

Fig. Maximum effort chart for Non - Striker

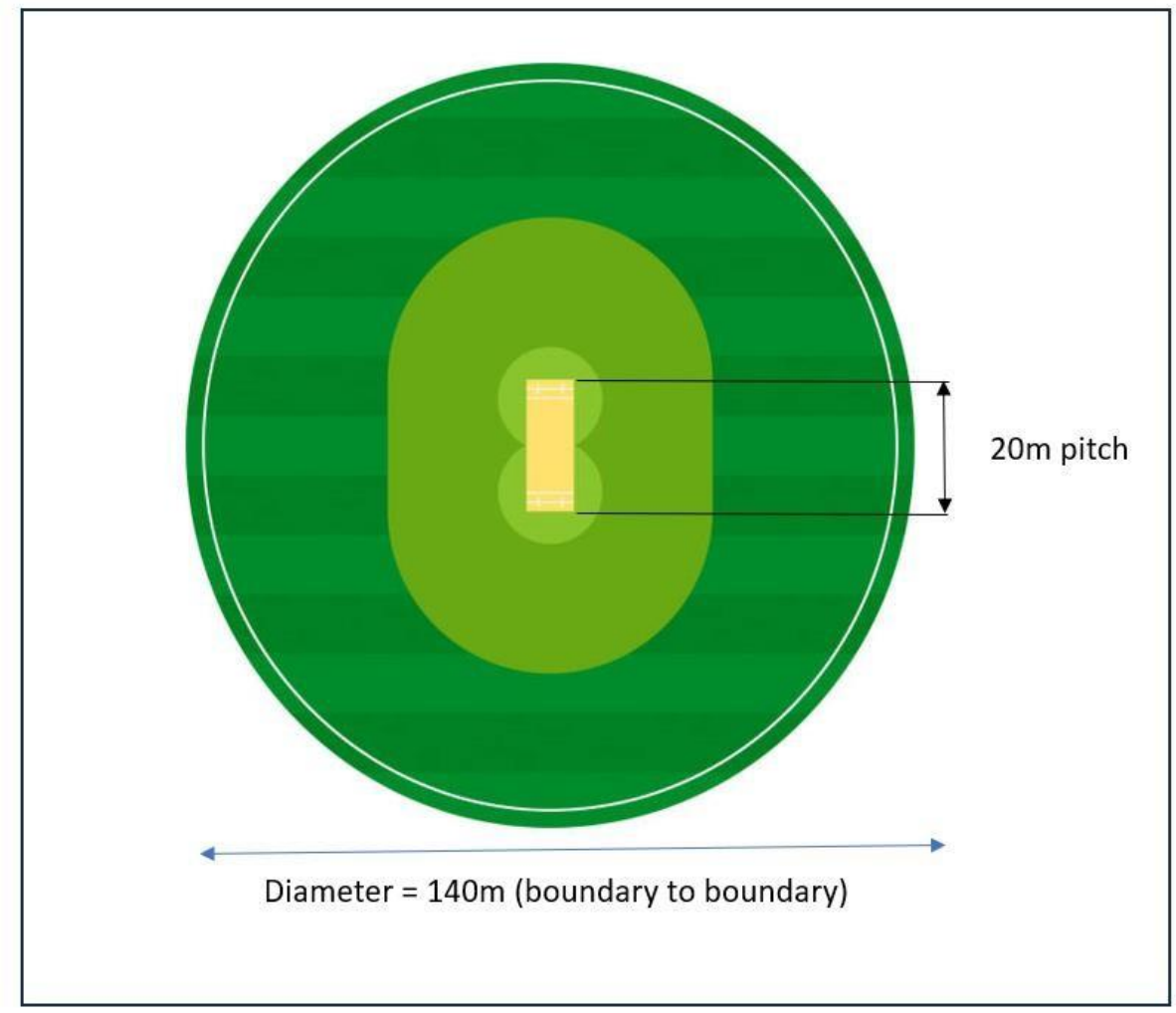

Fig. Circular shaped Wankhede stadium

Commentary : Oh my God! Something is happening out there on the ground**. Anyways, the ball has been given to the players and we are all set to go !!

What exactly happened? :

**The half portion of the ground (not containing the striker) is introduced with an magnetic field of upwards direction (seems as if it comes out of the ground) having magnitude 0.54 T

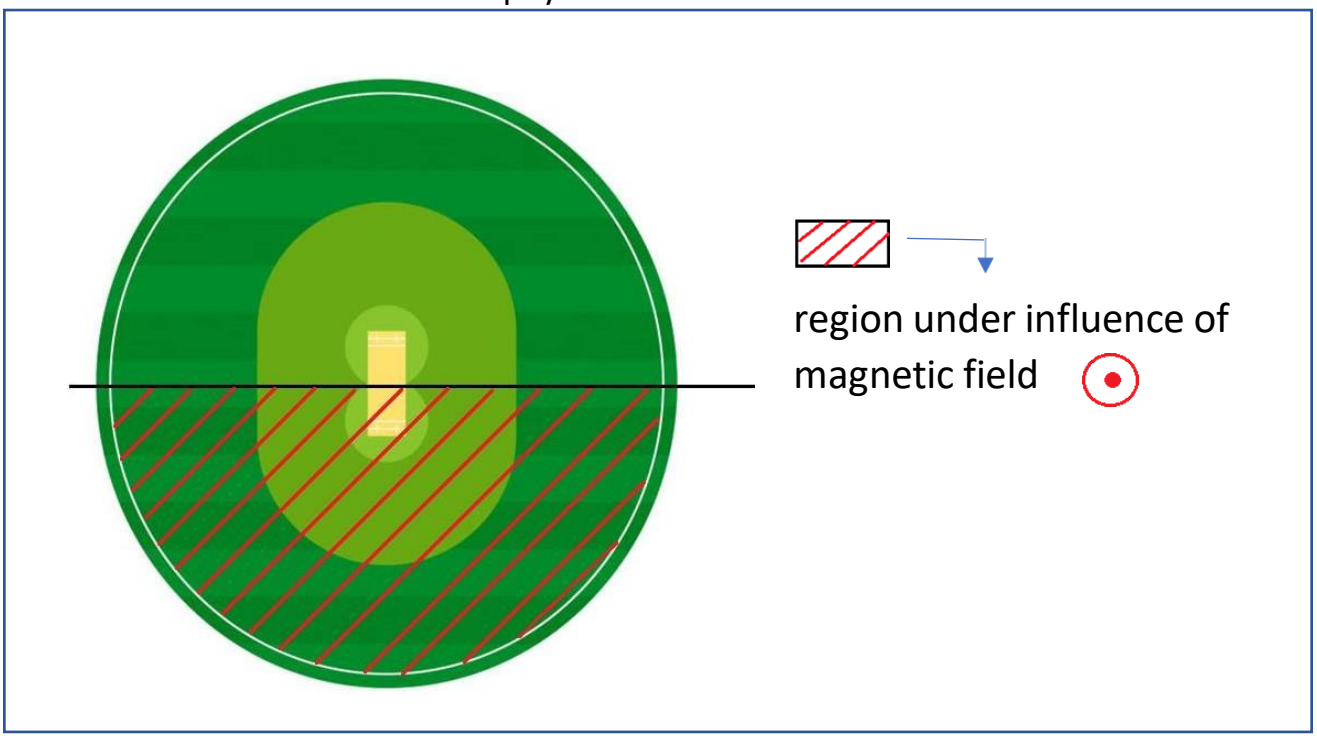

Fig. What exactly happened ?

Regarding the new ball :

- Mass : 160 g
- Charge : 164 mC
- Colour : White

Commentary : Man, I am just out of words…Just pitch the ball towards the batsman, I can't wait anymore.

Commentary : Oh, what a excellent toe crushing yorker just ahead of the stumps, to which batsman replies with a flick towards the leg side. The ball is been running towards the boundary along the ground…….

Commentary : Both the striker and the non striker have started running with their maximum efforts across the pitch, trying their level best !!

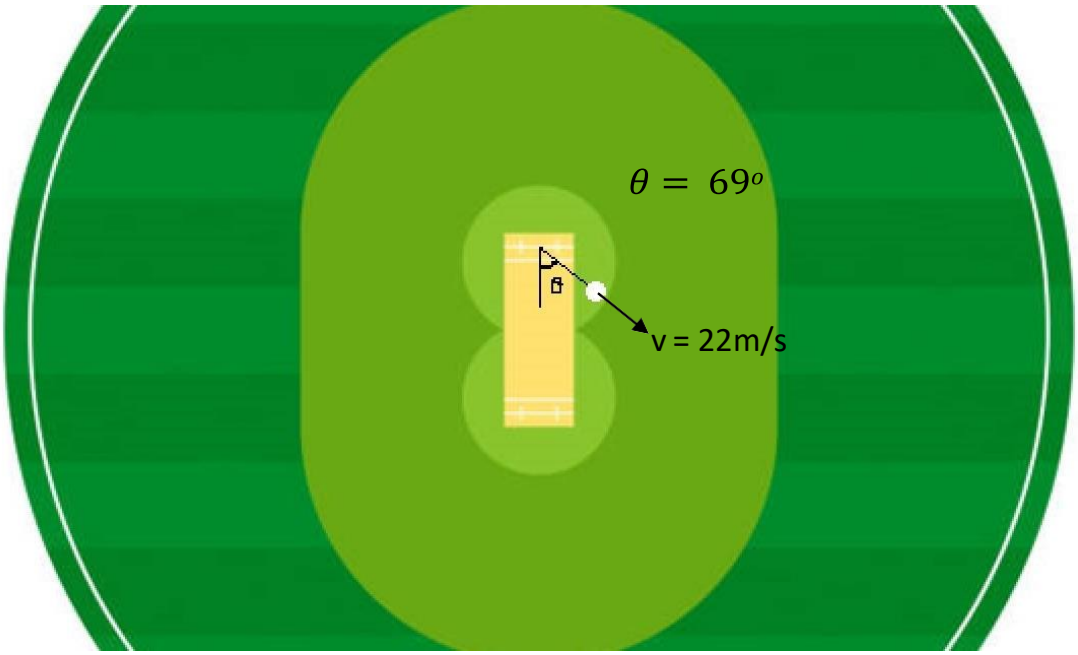

Fig. Last ball situation

In the figure above, v is the velocity of the ball just after the impact with the bat and θ the angle which the ball makes with the centre pitch line.

Commentary : Hey, watch out! What's happening in here, I just can't believe what's happening, Also, with me, my co-commentator friends, audience as well as the players themselves are just completely astonished and all the fielders are just statued.

Question Parts are on Next Page

Question Parts:

- Batting Team : Gujarat Titans (GT)
- Fielding Team : Mumbai Indians (MI)

(a) Why are there only 3 regions in the Maximum Effort Chart of both, striker and non-striker. Are you able to verify, if the velocity-time graphs are correct?

(b) In this scenario, can you predict What's the result of the match!?

(Assume ball to be point mass; there is no friction between ground and the ball)