Ticker Tapes

When investigating the motion of objects we can use a **ticker timer**. In most cases a ticker timer is connected to an alternating electricity supply (note, that there are other types of ticker timers which do work with direct current). The device uses the mains electricity frequency of 50 hertz to make 50 ticks per second. A metal strip is made to vibrate up and down 50 times every second according to the frequency of the mains. The vibrating metal strip strikes a paper tape through a carbon paper disc and so prints a dot on the tape 50 times per second. Therefore the time interval Δt between one dot and the next is always 1/50 second or 0,02 s. (But keep in mind that there are many questions where the frequency is NOT 50 Hz.)

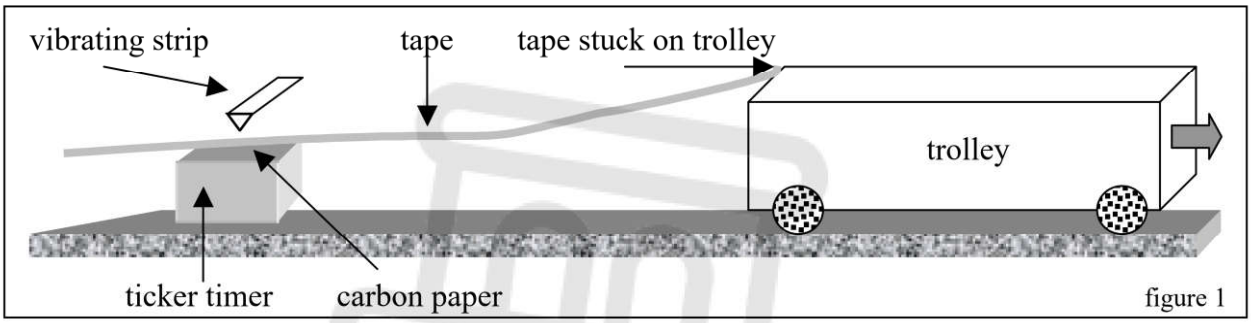
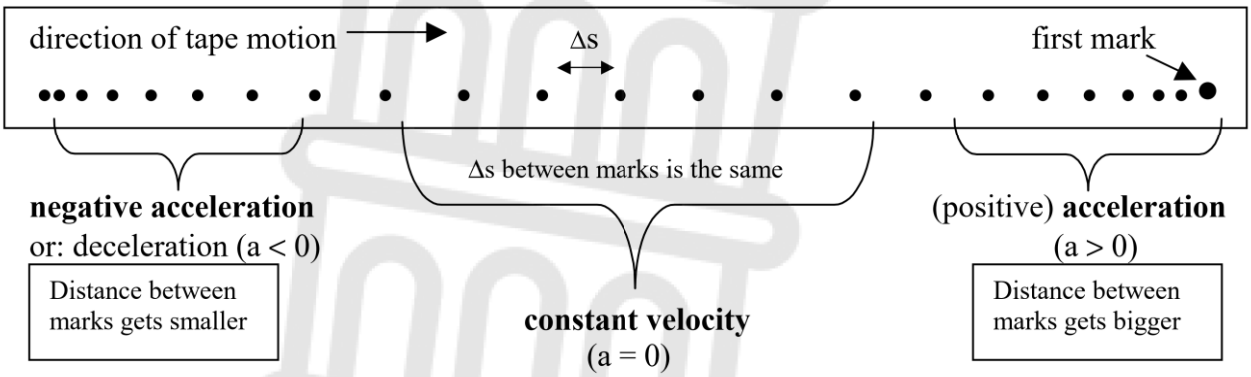


figure 1

Now let us assume, we give the trolley in figure 1 a push to the right side. This will give us a tape of the trolley's motion similar to the tape in the diagram below:



Note: This tape started from rest. The first mark is bigger than the others, indicating that the vibrating strip must have hit the place many times.
If the first mark is of the same size as the others it indicates that the vibrating strip hit there only once since the tape has been moving.

Frequency & Period

If the frequency of the ticker timer in use is 50 Hz, we know that the time interval Δt between two dots/marks is 0,02s.
Remember the relationship between frequency (unit: Hertz = 1/second) and period/time:

$$\text{Frequency} = \frac{\text{No of cycles}}{\text{second}} \qquad \text{Period} = \frac{1}{\text{frequency}}$$

Examples:

If frequency is 5 Hz ➔ Period (Δt between neighbouring marks) = 1/5 = 0,2 s
Frequency 10 Hz ➔ Period = 1/10 = 0,1 s
Frequency 20 Hz ➔ Period = 1/20 = 0,05 s

Problem Solving Techniques

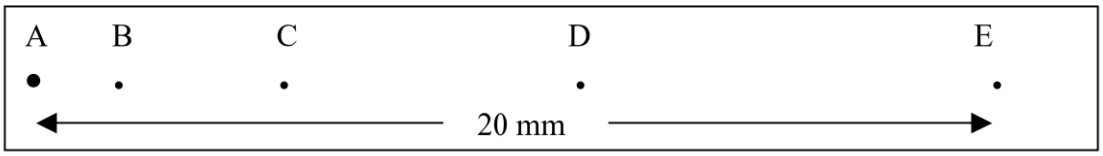
There are two types of ticker tape problems:

1. The tape starts from rest (remember: a big mark on the tape indicating the starting).

- Use **equations of motion**
- Make a **table**: u, v, a, t and s
  Initial velocity: u = 0 m/s
  Time t: determine from frequency. If the frequency is 50 Hz then the time between two dots is: time = 1/50 s = 0,02 second.
  Distance/displacement s: measure the distance between dots. Convert to metres.
  With three quantities given, we can find the elusive acceleration a.

Practice makes perfect, so let us solve a problem of this type.

Q1: You are given the ticker tape in the diagram below. If the ticker timer had a frequency of 4Hz find the acceleration of the tape.



The big, fat first mark shows that the tape started from rest hence we can apply equations of motion:

What is the time? Since frequency is 4 Hz we know that the time interval between two marks is
Period = $1/f$ = 1/4 s = 0,25 second.
Hence total time between A and E: 4 x 1/4s = 1 second

Table:
u = 0 m/s
v = ------
a = ?
s = 20 mm = 0,02 m
t = 1 sec (4 periods)

$s = ut + \frac{1}{2} a t^2$
$0{,}02\ m = 0 + \frac{1}{2} a (1s)^2$
$2 \times 0{,}02\ m/s^2 = 0{,}04\ m/s^2 = a$
acceleration of tape = 0,04 m/s^2

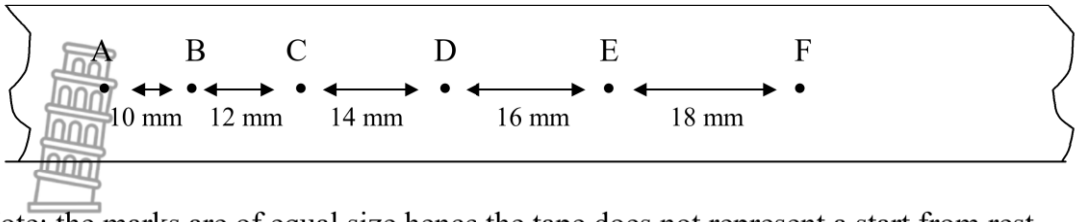
2. The tape does not start from rest (remember: all marks are of the same size.)

This type of question usually will ask you to find the average velocity and the acceleration of a moving system. It is more common to be found in the matriculation examination. You must be familiar with the concepts in the box below.

1.) **average velocity** = $\frac{\text{displacement}}{\text{time}}$

2.) **acceleration** = $\frac{\Delta \text{ velocity}}{\Delta t} = \frac{v - u}{\Delta t}$

Q2: You are given the ticker tape in the diagram below. If the ticker timer had a frequency of 10Hz find the acceleration of the tape.



Note: the marks are of equal size hence the tape does not represent a start from rest.

With this type of problem you always start with the first two intervals (from A to C) followed by the last two intervals (from D to E).

I. Average velocity between A and C:

displacement AC = 10mm + 12mm = 22 mm = 0,022 m
time between two marks: t = 1/10 s = 0,1 s
time AC = 0,2 s

$V_{average}$ = displacement/time
= 0,022/0,2
$V_{average}$ = 0,11 m/s

Important:
The **average velocity** between **A and C** gives the **instantaneous velocity at B**.
(B is in **terms of TIME** – and not distance – the halfway point between A and C.)

II. Average velocity between D and E:

$V_{average}$ = displacement/time
= 0,034/0,2
$V_{average}$ = 0,17 m/s

displacement =16+18 = 34mm = 0,034m
time: t = 2 x 0,1 = 0,2 s

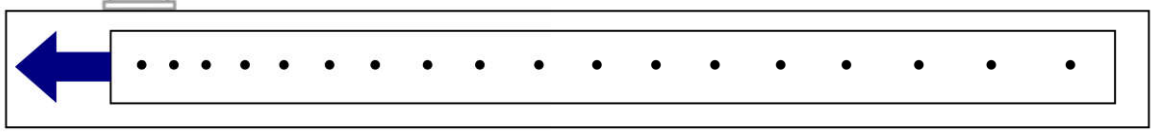
Remember: The average velocity between D and E gives you the instantaneous velocity at E.

To find the acceleration of the tape we take the velocity at B and E, which gives us Δ v.
Δ v = v – u = 0,17 m/s – 0,11 m/s = 0,06 m/s

To find Δ t we count the time intervals (spaces between dots) between B and E:
Δ t = 0,3 s.

$$\textbf{Acceleration} = \frac{v-u}{\Delta t} = \frac{0{,}06 \text{ m/s}}{0{,}3\text{s}} = \textbf{0,2 m.s}^{-2}$$

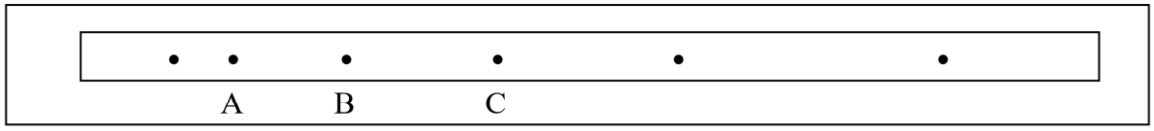
1. The motion of a trolley is recorded on a length of ticker tape, shown below.



What motion could be represented by this length of ticker tape?

A A trolley moving on a circular track.
B A trolley moving at a uniform velocity.
C A trolley moving freely up an inclined runway.
D A trolley pulled by a rubber band stretched to a constant length.

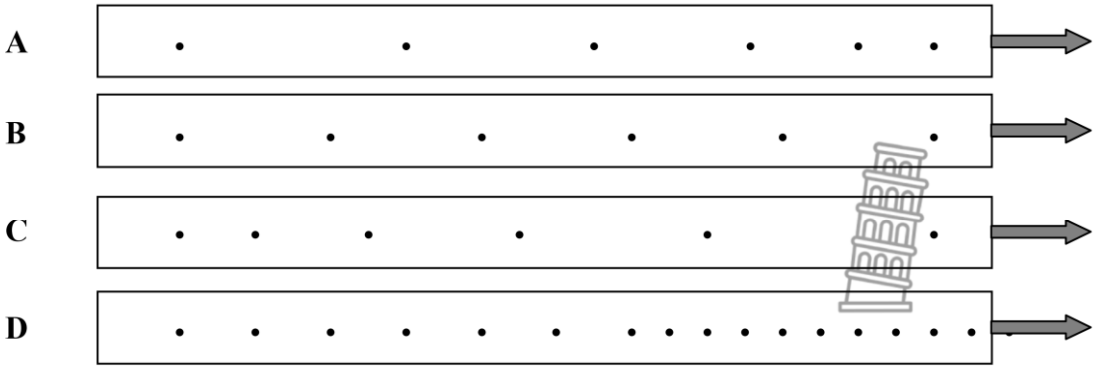
2. The diagram below shows a portion of a length of ticker tape obtained in an experiment in which a trolley, with the ticker tape attached, was pulled along by a constant force.



The experimenter wanted to calculate the instantaneous velocity of the trolley when the mark labeled B was made. If the period of vibration of the timer was T, which of the following correctly gives the instantaneous velocity at B?

A AC/T **B** AC/2T **C** BC/T **D** AB/T

3. The diagram below shows lengths of ticker tape from a timer in an experiment to distinguish between different kinds of motion. In each case the tape was being pulled to the right. Which tape shows an object decelerating while moving to the right?



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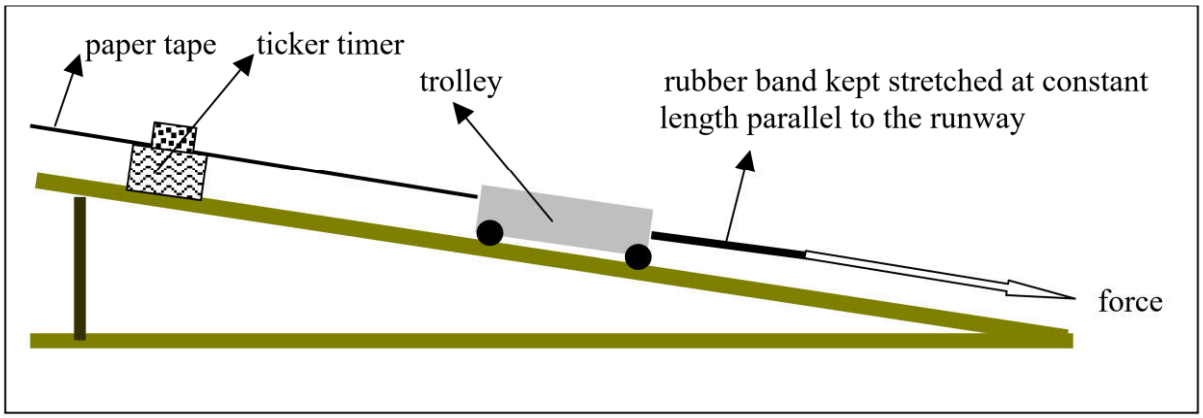
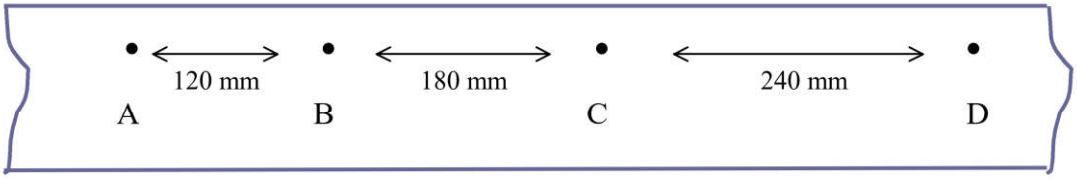
Structured Questions: Ticker Tapes

Q 1 (SG Mpumalanga, 1999)
An experiment was conducted to investigate the relationship between force and acceleration. It consisted of a ticker tape attached to a trolley as shown in the figure below. The tape was fed through a ticker timer, which made 50 dots per second on the tape. The trolley was placed on a gently sloping inclined plane. A force was applied by pulling on an elastic rubber attached to the trolley.



In one of the trials the 5th, 15th, 25th and 35th dots on the tape were marked A, B, C and D as shown below. The distance AB = 120 mm; BC = 180 mm and CD = 240 mm.



1. Calculate the time interval that elapsed between the 5th and 15th dot. (3)

2. Calculate the average speed of the trolley in each interval of
   i) AB
   ii) BC
   iii) CD (7)

3. from the values calculated above, find the average acceleration of the trolley in the intervals AC and BD. (5)

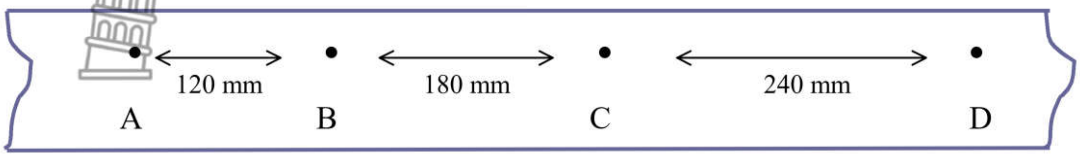
4. From the values of acceleration you calculated in 3., what can you say about the motion of the trolley? (2)

[17]

Ticker Tapes: Q1

1.1 frequency = 50 Hz 1 period (time between two dots) = 1/50 s = 0,02 s ✓
5^{th} to 15^{th} equals 10 periods ✓
∴ **Time** = 10 x 0,02 s = **0,2 s** ✓

1.2 (it is always helpful to make your own sketch)



i) average speed AB:

$$\text{Average speed} = \frac{\text{Distance}}{\text{Time}} = \frac{120\text{ mm}}{0{,}2\text{ s}} = \frac{0{,}12\text{m}}{0{,}2\text{s}} = \textbf{0,6 m/s} \quad ✓✓✓$$

ii) average speed BC:

$$v = \frac{180\text{ mm}}{0{,}2\text{ s}} = \frac{0{,}18\text{ m}}{0{,}2\text{ s}} = \textbf{0,9 m/s} \quad ✓✓$$

iii) average speed CD:

$$v = \frac{240\text{ mm}}{0{,}2\text{ s}} = \frac{0{,}24\text{ m}}{0{,}2\text{ s}} = \textbf{1,2 m/s} \quad ✓✓$$

1.3 average acceleration AC:

$$\text{Acceleration} = \frac{\Delta\text{ vel}}{\Delta\text{ time}} = \frac{0{,}9\text{ m/s} - 0{,}6\text{ m/s}}{0{,}2\text{ s}} = \frac{0{,}3\text{ m/s}}{0{,}2\text{ s}} = \textbf{1,5 m/s}^2$$

✓✓✓ (formula, substitution, answer)

NB How do we find Δt? 0,6 m/s is the instantaneous speed halfway in time between A and B, i.e. 0,1 s before B. 0,9 m/s is the same between B and C, i.e. 0,1 s after B. Hence Δt from 0,6m/s to 0,9m/s is 0,1s + 0,1s = 0,2 s.

Acceleration BC:

$$a = \frac{\Delta v}{\Delta t} = \frac{v - u}{\Delta t} = \frac{(1{,}2 - 0{,}9)\text{ m/s}}{0{,}2\text{ s}} = \textbf{1,5 m/s}^2 \quad ✓✓$$

1.4 The trolley moves with constant acceleration. ✓✓