Science Education Centre

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Physical Science

Equations of Motion (incl. Ticker Tapes)

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EQUATIONS OF MOTION

Summary of Relevant Content

There are **four equations of motion**:
Sometimes they are referred to as "The Kinematic Equations".

1.	$v = u + at$
2.	$s = ut + \frac{1}{2}at^2$
3.	$v^2 = u^2 + 2as$
4.	$s = \frac{1}{2}(u + v)t$

where			Unit
u	=	initial velocity	(m/s)
v	=	final velocity	(m/s)
a	=	acceleration	(m/s^2)
t	=	time	(s)
s	=	distance/displacement	(m)

ADVICE
Although the equations are given in the exam, it saves time and boosts self-confidence to memorise them. For memorisation write them on a piece of cardboard and display them in the lab/classroom so that they are visible to all.

REMEMBER

- All equations rely on acceleration (a) being **constant** over the time interval (t).
- If the acceleration is zero, then the second equation becomes $s = v \times t$ (since u = v)
  (never use $s = v \times t$ if $a \neq 0$)
- The fourth Equation is simply derived from:
  Displacement = average velocity x time taken.
  or: Distance = average speed x time taken.
- The 4 equations consist of 5 physical quantities: distance/displacement, time, initial & final velocity and acceleration. Each of the above equations has <u>four</u> unknowns. **To solve an equation with 4 unknows three must be given.**

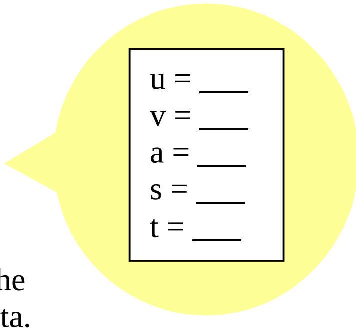
VERTICAL MOTION & MOTION OF FALLING BODIES

SUMMARY
(Ignore friction unless otherwise stated)
Free **falling objects** (no air resistance or other forces acting) **accelerate** downwards near the earth's surface **at g = 9,8 m/s^2**. (Gravitational acceleration is taken in the exam as 10 m/s^2.)

NOTE

1.) The value of gravitational acceleration (g) is an experimental value, which can be measured under certain conditions.
2.) Use equations of motion where the direction of acceleration (g = 10m/s^2) is downwards.
3.) "Drop" means u = 0 m/s (starting from rest).

TIPS FOR SOLVING PROBLEMS



- Always **draw a sketch/diagram** of the situation.
- In most cases **labelling the sketch** helps to solve the problem.
- Note down all the given data from the question. **Make a table** with these quantities.
- Provided **three values** are given, **select an equation** that has only a single unknown, and solve for that unknow. It may be the required unknown and if it is not, use it to find the required data.
- If there is more than one body in motion, find the quantity, which is the same for both, i.e. the **simultaneous quantity**. Then use different equations and solve for this unknown.
- Convert to **SI Units** if necessary.
- For **problems of falling bodies try to work downwards** where possible (u at the top is usually zero and g (downwards) = +10m/s^2).
- Where an object is projected upwards - **at the top of its travel it has zero velocity** (or speed), BUT **its acceleration is still 10 m/s^2 (g) downwards**. At the top of the motion the object is changing its direction, which means it is still undergoing a change in velocity and hence it is still accelerating.
- Provided there is no friction or outside interference, **the total energy of a free falling body remains constant**. (E_P + E_K = constant). For instance: If a body is dropped, E_P (at the top) = E_K (at the bottom), provided nothing happens to it on the way down. (This also applies to movement on an inclined plane).
- The **horizontal and vertical movements of a projectile are independent of each other** (provided air resistance is neglected). The vertical motion is one of uniform acceleration *g* and the horizontal motion is one of uniform speed (speed and not velocity because only the horizontal component of the motion remains constant throughout the flight).
- A body in "free fall", whether it is going up, down or horizontally has an acceleration of 10m/s^2 **downwards** - **always downwards,** and hence the force acting on it is also down.
- The second equation sometimes takes the form of a quadratic equation. Try to apply another method to **avoid solving quadratic equations**.
- If a problem involves **two moving objects** with **two velocities**, consider the velocity of the **slower object** to become **zero**. To do so, subtract the slower velocity from <u>both</u> objects.
- For problems involving guns, rifles, etc. take: **muzzle velocity = final velocity**.
- Starting **"from rest"** means **initial velocity = zero**.

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.)

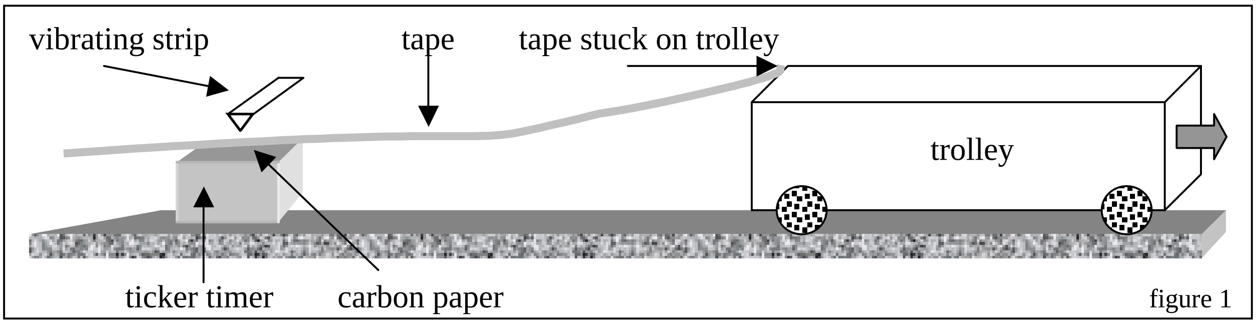
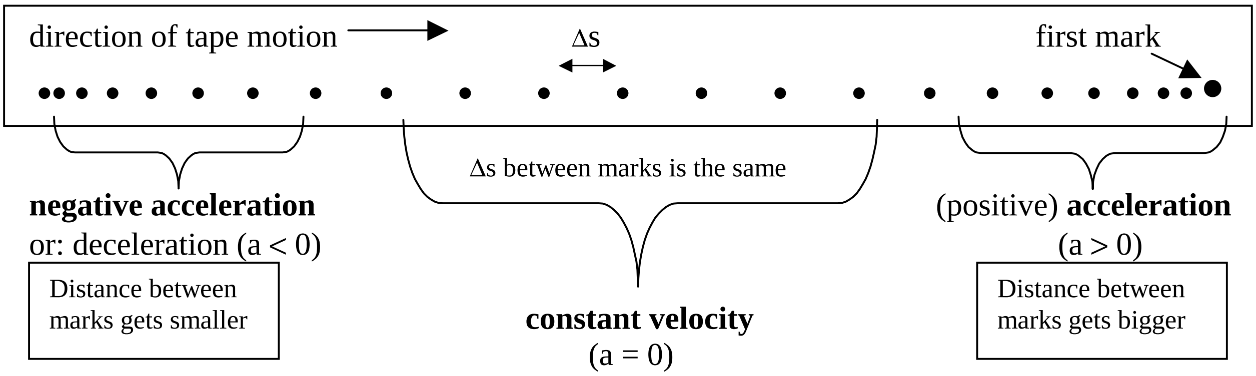


figure 1

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:

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

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

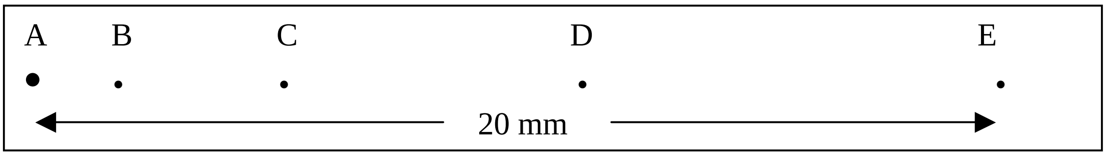
  Initial velocity: u = 0 m/s

  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)

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

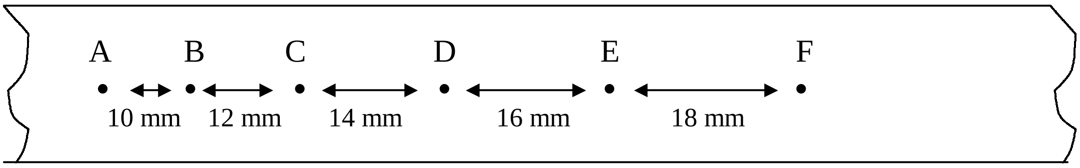
2. The tape does not start from rest (remember: all marks are of the same size.)

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 =** $\dfrac{\textbf{displacement}}{\textbf{time}}$

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

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
$\mathbf{V_{average}}$ **= 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
$\mathbf{V_{average}}$ **= 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.

<u>**Acceleration**</u> $= \dfrac{v - u}{\Delta t} = \dfrac{0{,}06 \text{ m/s}}{0{,}3\text{s}}$ **$= 0{,}2 \text{ m.s}^2$**

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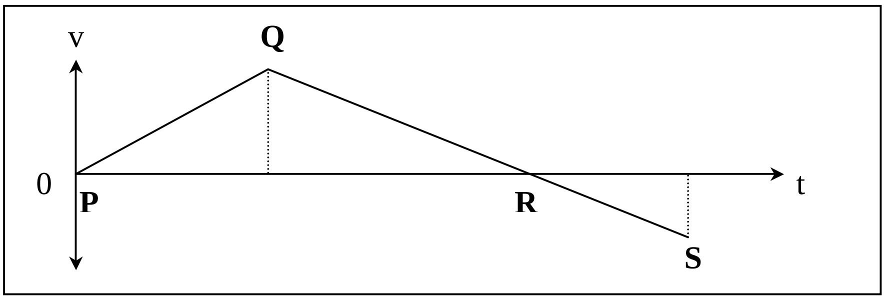
Topic: Equations of Motion
Worksheet 1: Multiple Choice Questions Time: 30 Minutes
Instructions: Make a cross over the letter A, B, C or D to show the correct answer.

1.) A motorcycle accelerates uniformly from rest along a straight road, reaching a speed of 200 km/h after 10,0 seconds. At what stage during the motion does the bike's speedometer needle pass the 100-km/h mark?

A halfway along the road
B 5,0 seconds after starting
C some distance after the halfway mark
D some time before 5 seconds

2.) Consider the following velocity-time graph of a car starting from rest in a straight line. At what time of the movement is the object the furthest from its starting point?



A P **B** Q **C** R **D** S

3.) Skydivers often leap from aircraft at great altitude, reaching "terminal velocity". Which of the following best explains the cause of this terminal velocity?

A gravity no longer acts on the skydivers because of their speed.
B gravity only accelerates all objects to a certain speed and no faster.
C atmospheric pressure, acting from all sides, keeps them up.
D the upward force on them caused by air resistance becomes equal to their weight.

4.) A car is travelling at **constant** acceleration along a straight road. Which one of the following quantities changes by the same amount in equal time intervals?

A displacement
B resultant force
C kinetic energy
D velocity

5.) A hunter points a dart **directly** at a monkey sitting on a tree. However, just as the hunter fires the dart the monkey drops from the branch.
The dart will …

A strike the monkey
B pass over the monkey
C pass below the monkey
D not enough information provided to answer the question.

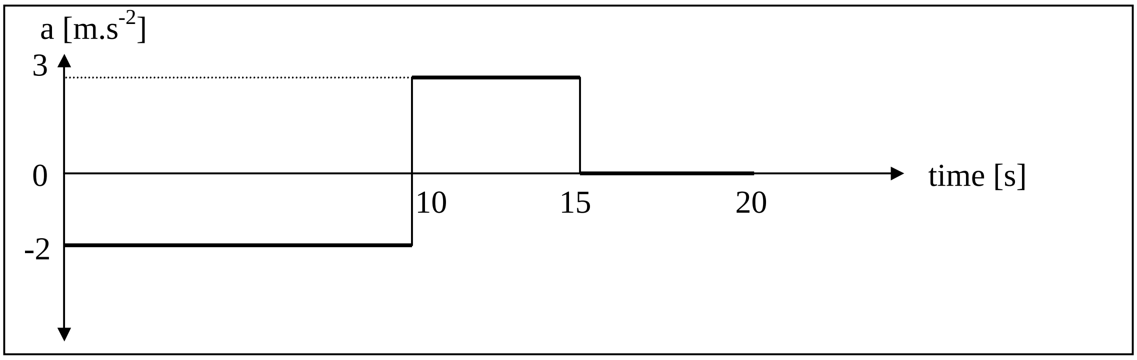
6.) A girl, standing on a bridge, throws a metal sphere vertically downward as hard as she can. Which statement concerning the acceleration of the stone after it has left her hand is true? (Ignore any effects of air resistance.)

A The sphere's acceleration is equal to "g".
B The sphere's acceleration is greater than "g".
C The sphere's acceleration is less than "g".
D The sphere's acceleration is at first greater than "g", then becomes equal to "g".

7.) How far does a stone fall in 1,0 s when dropped on earth, disregarding any air resistance?

A 1 m
B 5 m
C 10 m
D 20 m

Question 8 & 9 refer to the diagram below:
A car is moving on a straight, horizontal road in an easterly direction. The acceleration of the car for the following 20 s is shown in the graph as a function of time.



8.) The velocity of the car is …

A 5 m.s^{-1} west
B 25 m.s^{-1} west
C 5 m.s^{-1} east
D 25 m.s^{-1} east

9.) During the 20 seconds when is the car stationary?

A from 0 to 10 seconds
B from 10 to 15 seconds
C from 15 to 20 seconds
D never

10.) Which of the following will **not** effect on the acceleration of a falling object?

A Height of the object above sea level.
B Distance between centre of the earth and the object.
C Mass of the object.
D Mass of the earth.

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Topic: Equations of Motion
Worksheet 2: Multiple Choice Questions Time: 30 Minutes
Instructions: Make a cross over the letter A, B, C or D to show the correct answer.

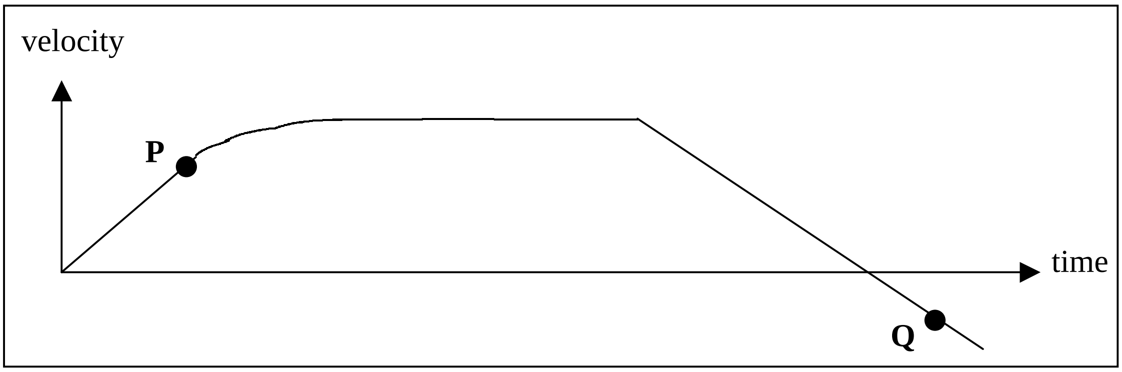
1.) A Ferrari racing car accelerates from 10 m/s to 25 m/s in 5 seconds. What is the average acceleration of the car?

A 3 m/s^2
B 5 m/s^2
C 15 m/s^2
D 25 m/s^2

2.) A ball is thrown vertically into the air and when it returns after an interval of 2 seconds, it is caught. Which one of the following statements is true if the acceleration due to gravity is 10 m/s^2 and air resistance can be neglected:

A The acceleration after it leaves the hand is 10 m/s^2 downwards.
B The maximum height it reaches does not depend on the force of gravity.
C The time taken for the descending motion does not equal the time taken for the ascending motion.
D The acceleration at the top of its flight is 10 m/s^2.

Questions **3 & 4** refer to the diagram below, which shows a velocity-time graph plotted for the motion of a car.



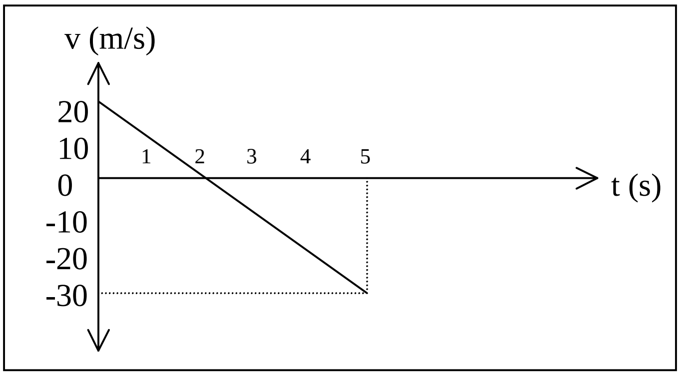
3.) At point P, the car must be

A travelling at constant velocity
B climbing a hill
C accelerating
D decelerating

4.) At point Q, the car must be

A travelling downhill
B stationary
C reducing speed
D travelling in the reverse direction

5.) A ball is thrown vertically up from the top of a building and the graph below shows the variation of its velocity with time up to the 5th second.

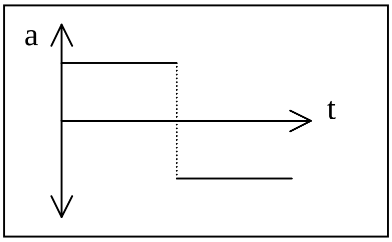


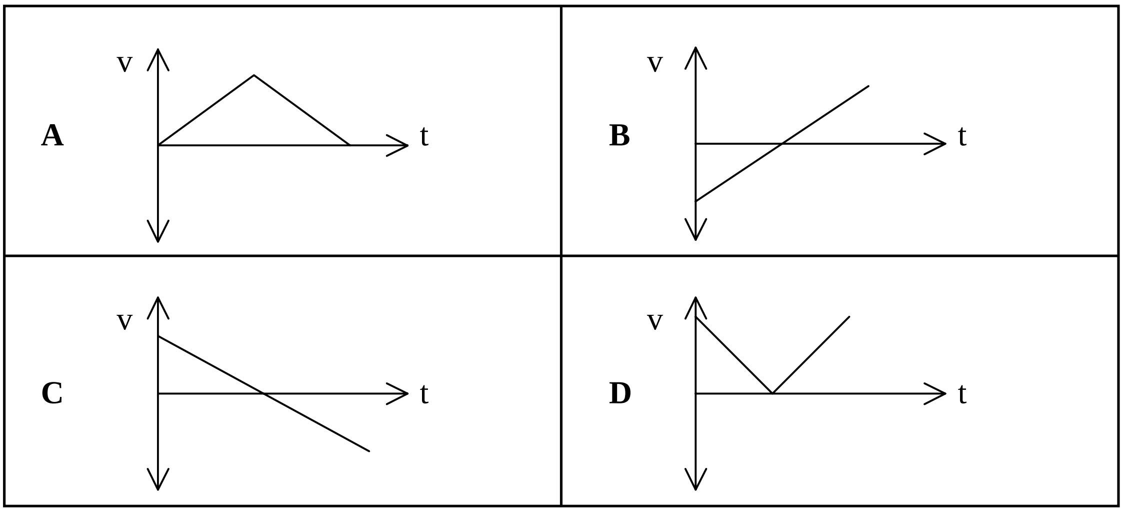
At the end of its journey (as shown by the graph) the ball is …

A back at its point of projection.
B 25 m from the point of projection and moving downwards.
C 45 m from the point of projection and moving downwards.
D 25 m from the point of projection and moving upwards.

6.) Which of the given velocity : time graphs matches the given acceleration : time graph?

given:





7.) If the acceleration of a moving object is zero, then …

A the object is moving at constant velocity.
B the object is coming to rest.
C the object is changing direction.
D the object is changing its speed.

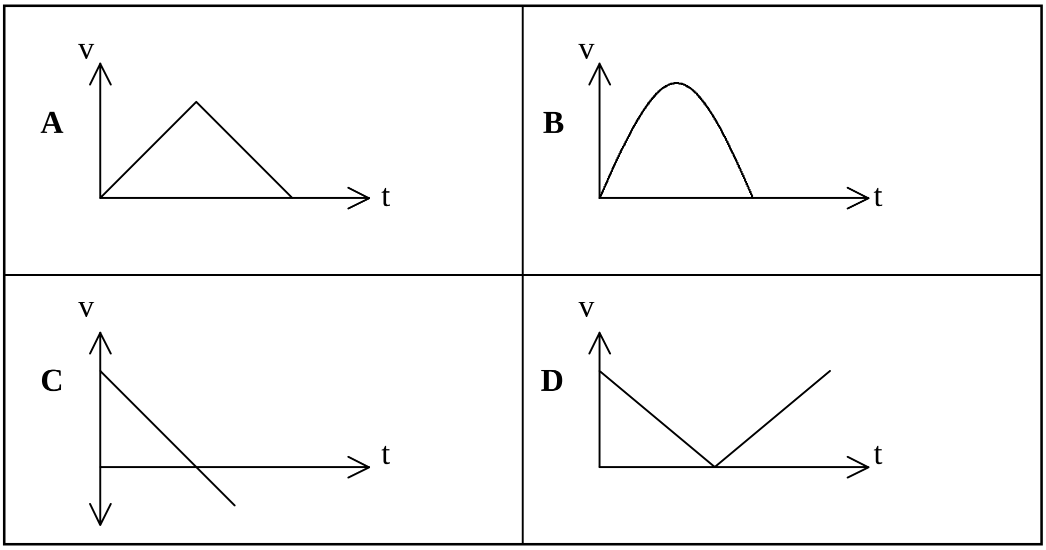
8.) A parachutist lands on the ground at a speed of 6 m/s. The height from which a free falling-object will have to fall to reach the same speed is …

A 0,30 m
B 1,80 m
C 3,60 m
D 60,0 m

9.) A ball is thrown vertically upwards. If air resistance is ignored, the ball will move with constant …

A velocity
B momentum
C acceleration
D potential energy

10.) A ball is thrown vertically upwards. Ignore air resistance. Take the upward motion as positive. Which one of the following graphs represents the velocity of the ball as a function of time?



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Topic: Equations of Motion
Worksheet 3: Multiple Choice Questions Time: 30 Minutes
Instructions: Make a cross over the letter A, B, C or D to show the correct answer.

1.) An object moving at 18 m/s suddenly experiences an acceleration of 2 m/s^2. What will be its velocity 2 seconds after it started accelerating?

A 9 m/s **B** 20 m/s **C** 22 m/s **D** 36 m/s

2.) A parachutist is descending with uniform velocity. This indicates that he is experiencing …

A no forces at all
B zero resultant force
C a downward resultant force
D an upward resultant force

3.) A soccer ball is thrown vertically upwards. At the top of its path, when the ball reaches the maximum height, its acceleration is …

A zero
B changes from upward to downward
C upward
D downward

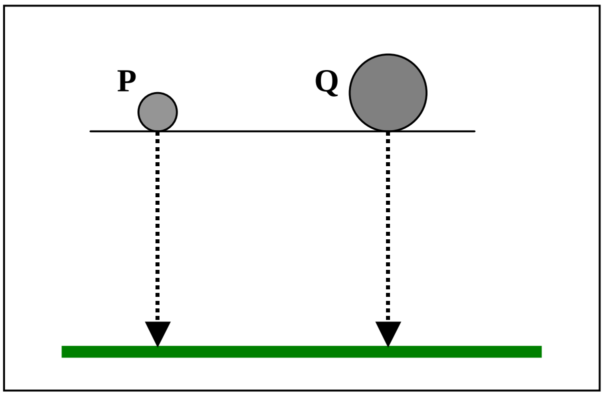
4.) An object is dropped from a tall building. How does the distance, which it falls in the first 3 seconds, compare with the distance it falls during the first second? (Ignore air resistance.)

A nine times as far
B six times as far
C three times as far
D $\sqrt{3}$ times as far

5.) A car is travelling at constant acceleration along a road. Which one of the following quantities changes by the same amount in equal time intervals?

A displacement
B resultant force
C velocity
D kinetic energy

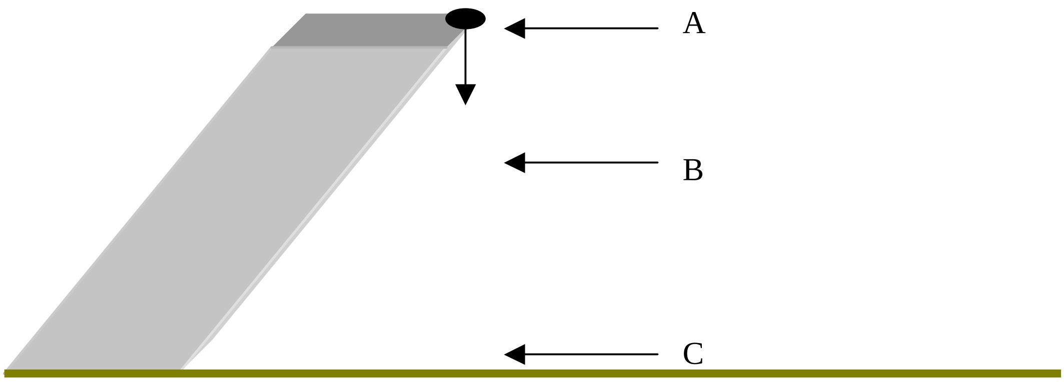
6.) Two heavy metal spheres P and Q are simultaneously dropped from the same height. P is much smaller than Q.



Ignore the effect of air resistance. Which one of the following is the correct observation and possible reason for what happens?

	observation	**possible reason**
A	they reach the floor simultaneously	gravitational forces are equal for both spheres
B	P reaches the floor first	smaller objects always fall 'faster' than bigger ones
C	Q reaches the floor first	the earth's force of gravity is greater on the heavier object
D	they reach the floor simultaneously	the gravitational acceleration is the same for both

7.) A ball falls vertically from rest from a high cliff from point A as shown in the sketch.



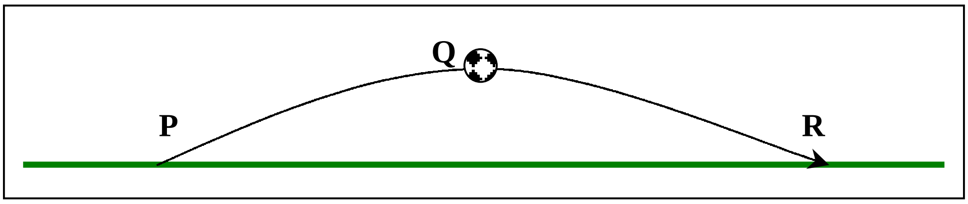
At point B the ball reaches its terminal velocity. While the ball is falling from B to C, its kinetic energy will

A be zero
B increase
C decrease
D remain constant

8.) A rock is thrown vertically upwards with a speed 'v' from the edge of a cliff. At the same moment, a second rock is thrown vertically downwards with the same initial speed 'v'. Which of the following statements regarding the motion of the rocks is true (ignore air resistance.)?

A The rock which was thrown upwards reaches the bottom of the cliff with a higher velocity.
B The rock which was thrown downwards reaches the bottom of the cliff with a higher velocity.
C Both rocks reach the bottom of the cliff with the same velocity at the same time.
D Both rocks reach the bottom of the cliff with the same velocity but at different times.

9.) The path PQR of a soccer ball kicked from a point P on the ground is shown in the diagram below. At point Q, the ball is at its maximum height.



Which ONE of the following vectors may represent the acceleration due to gravity of the ball at Q?

10.) A hunter fires his rifle horizontally at the same instant an identical shell to the fired one falls out of the rifle magazine at the same vertical height. Which shell strikes the ground first, the fired or the dropped?

A Both hit the ground at the same time
B The fired shell hits the ground first.
C The dropped shell hits the ground first.
D More information is required to answer the question.

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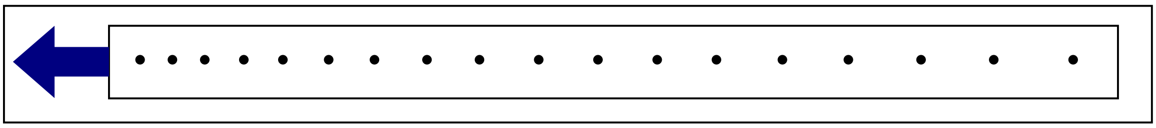
Topic: Ticker Tapes
Worksheet 4: Multiple Choice Questions Time: 10 Minutes
Instructions: Make a cross over the letter A, B, C or D to show the correct answer.

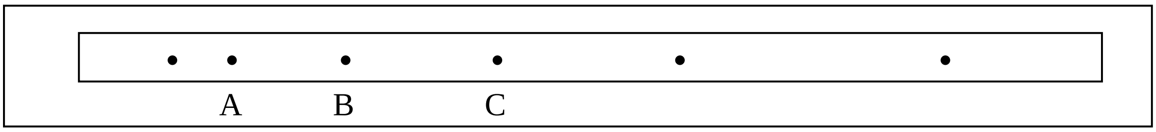
1. The motion of a trolley is recorded on a length of ticker tape, shown below.



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.

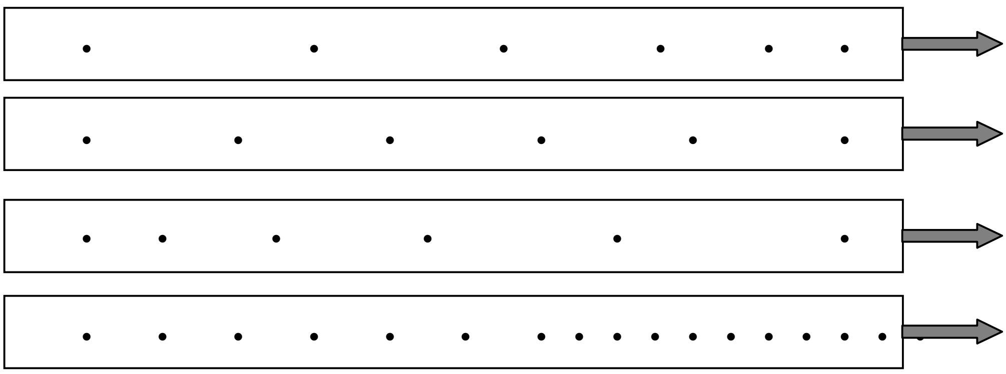


The experimenter wanted to calculate the instantaneous velocity of the trolley when the mark labeled B was made. If the period of vibration of the timer was T, which of the following correctly gives the instantaneous velocity at B?

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

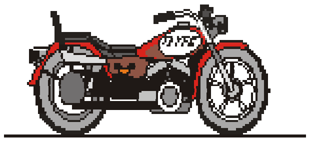
3. The diagram below shows lengths of ticker tape from a timer in an experiment to distinguish between different kinds of motion. In each case the tape was being pulled to the right. Which tape shows an object decelerating while moving to the right?

A
B
C
D



Structured Questions: Horizontal & Vertical Motion

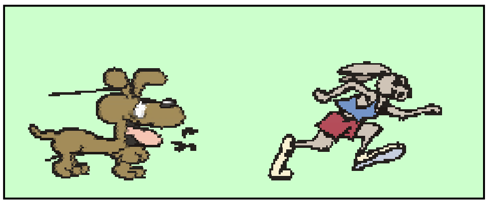
Q1 A motorcycle is starting from rest with an acceleration of $3 m/s^2$. Find



a) the distance travelled in 6 seconds.
b) its velocity after 6 s.
c) its average velocity during the first 6 s.
d) the distance covered by the time the motorcycle attains a velocity of 36 m/s.

Q2 Car A is 200 m behind car B. Both are travelling at a constant 90 km/hr in the same direction. A then accelerates and passes B in 20 seconds. Find
a) the distance car A travels in the 20 sec.
b) the acceleration of car A (assumed to be constant).
c) the speed of car A at the end of the 20 seconds.

Q3 A dog running at 10 m/s is 30 m behind a rabbit running at 5 m/s. When will the dog catch up with the rabbit? (Assume both velocities remain constant throughout the chase.)

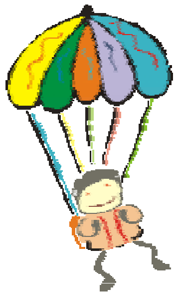


Q4 Thembi rides her motorcycle at 20 m/s. Suddenly she sees a row of stones blocking the road 170 m ahead. She applies the brakes and the motorcycle is decelerated at $2 m/s^2$. Will she be able to stop in time?

Q5 A balloon is ascending with a velocity of 20 m/s. When the balloon is 480 m above the ground, a coin is dropped from it. How long will it take for the coin to hit the ground (ignore air resistance).

Q6 A hot air balloon rises at a constant velocity of 2 m/s at an angle of 30^0 to the horizontal. The balloon is in flight for 6 seconds when a parcel is dropped from it.
Calculate
a) the height the balloon was at when the parcel fell.
b) the time taken for the parcel to fall to the ground.
c) the height the balloon was at when the parcel struck the ground.

Q7 A skydiver jumps from a height of 1500 m and falls freely for the first 10 seconds. He then opens his parachute and accelerates at -18 m/s^2 until his final speed is 10 m/s. This speed is maintained until he lands. What is the time taken for the entire trip?

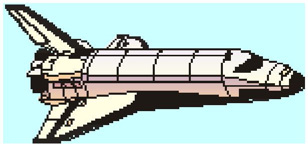


Q8 A rifle with a muzzle velocity of 200 m/s is fired with its barrel horizontal at a height of 1,5 m above ground. Calculate

a) the length of time the bullet is in the air.

b) the distance from the rifle the bullet lands.

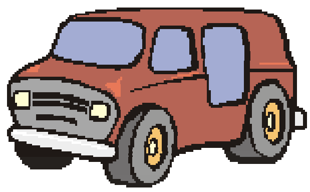
Q9 **(SG)** A space shuttle, which is coming in to land, touches down on the runway with a horizontal velocity of 100 $m.s^{-1}$. It then experiences a negative acceleration of $5m.s^{-1}$ of $5m.s^{2}$ until it comes to a standstill. Calculate the minimum length that the runway must be. (5)



Q10 **(HG)** Mandla's personal best time for 100 m is 10,8 s. At the 2001 Soweto championships he ran the first 20 m of the 100 m race in a time of 3,2 s.

1. Calculate the average speed for the first 20 m of the race. (3)
2. For the first 20 m Mandla's acceleration is constant. Calculate the magnitude of the acceleration. (4)
3. Calculate the speed after the first 20 m of the race. (4)
4. Will Mandla be able to better his personal best if he maintains his speed after the first 20 m of the race? Motivate your answer with a calculation. (5)

Q11 **(SG)** Thobile operates a taxi service between Johannesburg and Durban. The distance between the terminals in the two cities is 600 km. Thobile starts the trip from Johannesburg at 06:00 and reaches Harrismith, which is 240 km from Johannesburg, at 09:00.

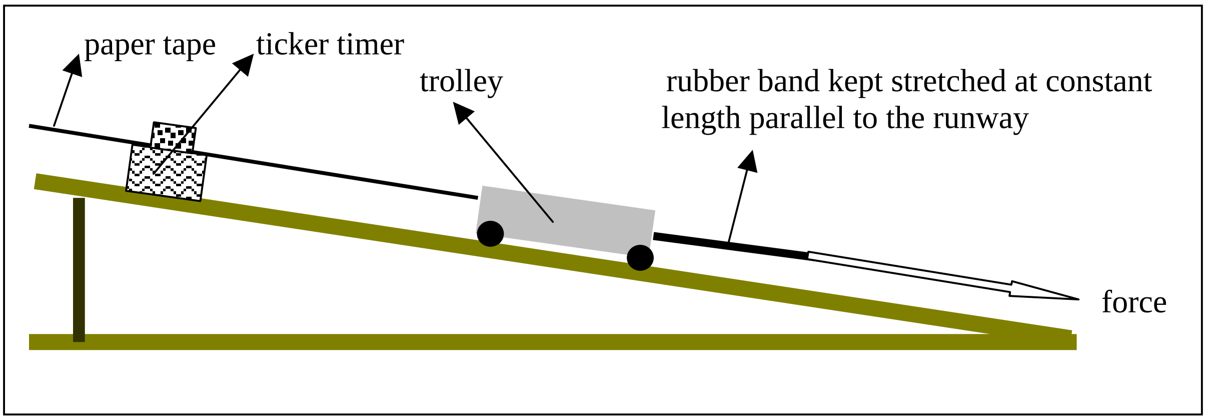


1. Calculate Thobile's average speed between Johannesburg and Durban
   a) in $km.s^{-1}$ (3)
   and
   b) in $m.s^{-1}$ (3)
2. After allowing her passengers a breakfast break of ½ hour at Harrismith, she drives to Mooi River, which is 200 km from Harrismith. This part of the trip takes 2 hours. At what time will she reach Durban if her average speed between Mooi River and Durban is $80km.hr^{-1}$? (6)

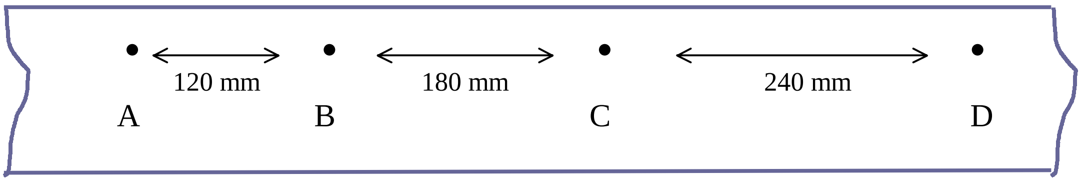
Structured Questions: Ticker Tapes

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)

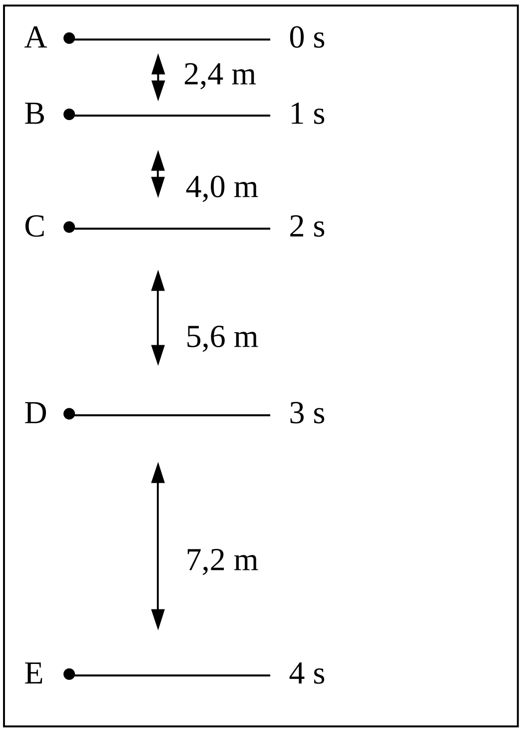
2. Calculate the average speed of the trolley in each interval of
   i) AB
   ii) BC
   iii) CD (7)

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]

Q 2 (HG, Gauteng 1999)
South Africa's first visitors to the moon want to know what the acceleration due to gravity on the moon is. They throw a piece of moon rock from the roof of a moon hotel and note the distances through which the stone has fallen in each second.
The results follow:



Make use of the information above and calculate
(remember that the initial velocity was not zero)

a) the average velocity during the
   i) first second
   ii) fourth second (6)

b) the acceleration due to gravity on the moon. (5)

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ANSWERS TO STRUCTURED QUESTIONS:
HORIZONTAL & VERTICAL MOTION

Q1

table:

u	= 0m/s
v	=
a	= 3 m/s^2
s	= *54m*
t	= 6s

a) distance covered after 6 s - 2nd equation $s = ut + 1/2at^2 = 0 + 1/2 \times 3m/s^2 \times (6s)^2$

$s = 1/2 \cdot 3m \cdot 36 = 3 \cdot 18$ m

$\mathbf{s = 54\ m}$

b) velocity after 6s: 1st equation: $v = u + a \cdot t = 0 + 3m/s^2 \cdot 6s$

v = 18 m/s in direction of moving motorcycle

c) average velocity during motion: $v_{average} = (u + v) \cdot 1/2 = (0+18)1/2$

$\mathbf{v_{average}}$**= 9 m/s in direction of moving motorcycle**

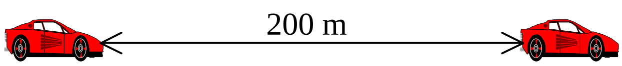
d) distance travelled until motorcycle reaches 36 m/s: v = 36 m/s u = 0 m/s

3rd equation: $v^2 = u^2 + 2as$ $\therefore$ $s = v^2/2a = (36)^2/2{\cdot}3 = (36)(36)/6 = 6 \cdot 36$ m

$\mathbf{s = 216\ m}$

Q2
Solution part a)

1.) Start with a **sketch**:



car A car B

2.) fill in the u,v,a,s,t **table**:

for car A	for car B
u = 90 km/hr = 25 m/s	u = 90 km/hr = 25 m/s
v =	v = 90 km.hr = 25 m/s
a =	a = 0
s = *700 m*	s = *500m*
t = 20 s	t = 20 seconds

3.) from the car B data we can find the distance covered in given time interval of 20s:

select 2nd equation: $s = ut + 1/2\ at^2$

$s = ut = 25m/s \times 20\ s = 500$ m

therefore: total **distance car A has covered** in 20 seconds is 500 m + 200 m **= 700 m**

b) acceleration of car A:

take 2nd equation again and rewrite: $s = ut + 1/2\ at^2 \quad \therefore \quad a = \dfrac{2\ (s - ut)}{t^2}$

$$\mathbf{a} = \frac{2\ (700m - 25m/s \times 20s)}{(20)(20)} = \frac{400m}{400s^2} = \mathbf{1\ m/s^2}$$

c) final velocity of car A: take 1st equation:

(final velocity) $\mathbf{v} = u + a > t = 25\ m/s + 1\ m/s^2 > 20s \quad = \mathbf{45\ m/s}$

Q3 Apply the following **method: stop the slower object**, in our example it is the rabbit. We can stop the rabbit by subtracting -5 m/s from its velocity, but we have to subtract the same velocity from the dog's velocity. Therefore we can draw the following table:

dog	rabbit
u = 5 m/s	u = 0 m/s
v = 5 m/s	v = 0 m/s
a = 0	a = 0
s = 30 m	s =
t =	t =

2nd equation: $s = ut + 1/2\ at^2$

$30\ m = (5\ m/s)\ t + 0$

$\therefore \quad \mathbf{t} = 30s/5 =$ **6 seconds**

Q4 table:

u	=	20 m/s
v	=	0 m/s
a	=	$-2\ m/s^2$
s	=	170 m
t	=	*10 s*

select 1st equation to find the time t:

$v = u + a\,t$

$\therefore\ t = (v - u)/a$

$= (-20m/s) \div (-2m/s^2) = 10\ s$

apply 2nd equation to find whether the vehicle can stop in 10s without crashing into rocks:

$s = ut + 1/2\ at^2$

$\mathbf{s} = 20m/s \cdot 10s - 1/2 \cdot (2m/s^2) \cdot (10)^2 = 200\ m - 100\ m = \mathbf{100\ m}$

Yes, since stopping distance is 100 m.

Q5 sketch:

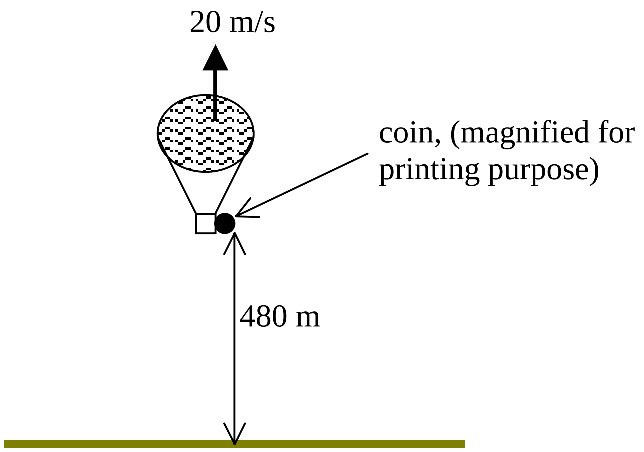


table:

u	=	-20 m/s (up)
v	=	+*100 m/s* (down)
a	=	$10\ m/s^2$ (down)
s	=	480 m
t	=	

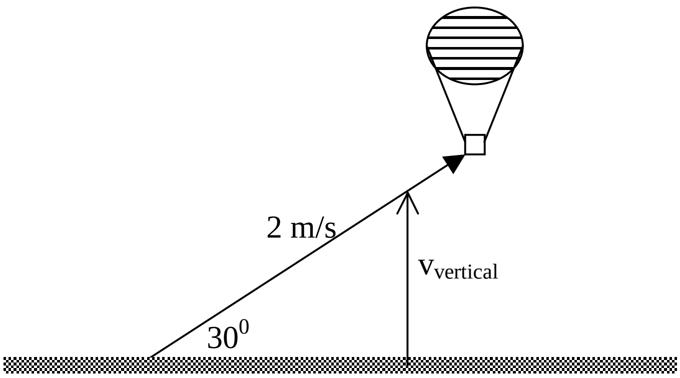
(Avoid 2nd equation since it will provide you only with a quadratic equation.)

Apply 3rd equation to determine final velocity:
$v^2 = u^2 + 2as = (-20 m/s)^2 + 2 \cdot 10 m/s^2 \cdot 480 m = 400 + 9600 = 10000 m^2/s^2$
$v = \pm 100 m/s$
final velocity: $v = 100 m/s$

to find the time use 2nd equation: $v = u + a t$

$\therefore t = (v - u)/a$
$= [100 - (-20)] \div 10 = 120 \div 10$
$t = 12$ seconds

Q6 Sketch:



first step: find vertical velocity
$\sin 30^0 = v_{verti} / hyp$
$\therefore v_{verti} = \sin 30^0 \cdot hyp = 1/2 \cdot 2 m/s$
$v_{verti} = 1 m/s$

table for balloon:
(u = v, since no acceleration)

u_{verti}	=	1 m/s
v_{verti}	=	1 m/s
a	=	0
s	=	*6 m*
t	=	6 s

a) let's find the height of the balloon after the time of 6 seconds has elapsed:
2nd equation: $s = ut + 1/2 at^2$ $a = 0$ $\therefore$ $s = u t = 1 m/s \cdot 6 s = 6 m$
height of balloon when parcel fell= 6 m.

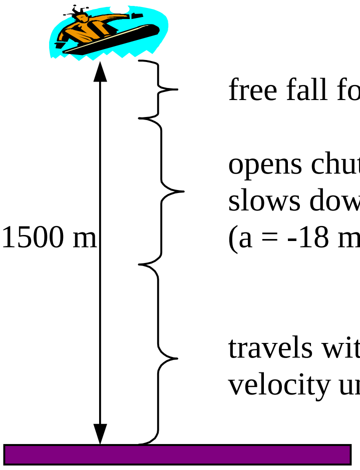
b) table for the parcel:

u_{verti}	=	-1 m/s (up)
v_{verti}	=	*11 m/s*
a	=	$10 m/s^2$ (down)
s	=	6 m
t	=	

start with finding v:
apply 3rd equation:
$v^2 = u^2 + 2as$
$= 1 + 20 \cdot 6 = 121 m^2/s^2$
$\therefore$ $\underline{v = 11 m/s}$

4th equation: $s = 1/2 (u + v) \cdot t$ $\therefore t = 2s/(u+v) = 12m/(-1m/s + 11m/s) = 12/10 s$
$t = 1{,}2$ seconds

Q7 Sketch:



1500 m

free fall for 10 seconds **T I**

opens chute and
slows down to 10 m/s **T II**
(a = -18 m/s^2)

travels with terminal
velocity until landing **T III**

table for **T I**

$u = 0$ m/s
$v = -100$ m/s
$a = 10$ m/s^2 ↓
$s = $ *500 m*
$t = 10$ s

1.) we can find distance:
$s = 0 + 1/2\, a\, t^2$
$= 5 \cdot 100$
$\underline{s = 500 \text{ m}}$

2.) v: $v^2 = u^2 + 2as$
$= 0 + 20{\cdot}500 = 10000$ m/s^2
$\therefore\ \underline{v = -100 \text{ m/s}}$

NB velocity is negative since we took $a = +10$m/s^2

Now we are in a position to draw a comprehensive table for **T II**:

$u = -100$ m/s
$v = -10$ m/s
$a = -18$ m/s^2
$s = $ *-275 m*
$t = $ *5 s*

find time for T II by applying 1st equation:
$v = u + at$
$t = (v - u)/a = (-100 + 10)/-18 = 90/18 = 5$ s
$\underline{t = 5 \text{ seconds}}$

But we have to find the distance travelled in 5 seconds to determine the distance travelled in
T III:
$s = 1/2\,(u + v)\,t = 1/2\,(-100 + (-10))\,5 = 5/2\,(-110) = 5 \cdot -55 = -\underline{275 \text{ m}}$

Table for TIII

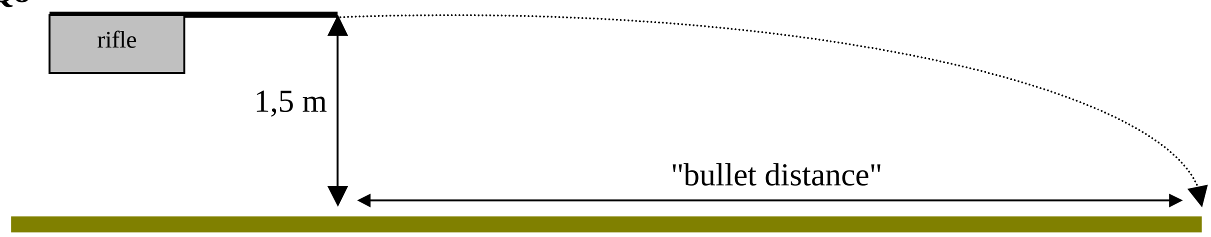
$u = -10$ m/s
$v = -10$ m/s
$a = 0$
$s = $ *725 m*
$t = $ *72,5 s*

distance travelled in TIII:
1500 m
\- 500 m
\- 275 m
725 m

Time for T III: vel. = distance/time = s/t
time = distance/velocity
= 725 m ÷ 10 m/s = 72,5

total time (TI+TII+TIII) = 10 s + 5 s + 72,5 s = **<u>87,5 seconds</u>**

Q8



table

u	=	0 m/s
v	=	200 m/s (horizontal)
a	=	10 m/s^2 (down)
s	=	1,5 m
t	=	*0,55 s*

a) time bullet is in the air:
vertical component of motion is independent of horizontal component of motion. Therefore the time for bullet being in the air can be calculated by applying 2nd equation:
$s = ut + 1/2\ a\ t^2$
$t^2 = 2s/a = 2 \cdot 1{,}5\ m/10m.s^{-2} = 0{,}3\ s^2$
$t = \sqrt{0{,}3}\ s$
t = 0,55 seconds

b) distance bullet has travelled in 0,55 s:
velocity = distance/time
distance = (muzzle) velocity time
= 200 m/s x $\sqrt{0{,}3}$ s
= 200m x 0,55 = 110 m (using $\sqrt{0{,}3}$ s the distance comes to 109,50 m)

"bullet distance" = 109,5 m

Q9 1.) Table with given data:

u	=100 m/s
v	= 0 (shuttle coming to rest)
a	= - 5 m/s^2
s	= ???
t	=

Using: $v^2 = u^2 + 2as$ ✓
$0 = 100^2 + 2 \cdot (-5) \cdot s$ ✓
$1 = 10000 - 10s$ ✓
$10s = 10000$
s = 1000 m ✓
⇨ **length of runway at least 1000 m in direction of landing shuttle.** ✓

Q10 **1. average speed?**

Average speed = distance ÷ time ✓

= 20 m ÷ 3,2 s ✓

= 6,25 m/s ✓

2. acceleration for 20m? table:

u	=	0 m/s
v	=	
a	=	?
s	=	20 m
t	=	3,2 s

using:

$s = ut + \frac{1}{2}at^2$ ✓

$20 = 0 + \frac{1}{2}a(3,2)^2$ ✓

$\therefore a = (20 \times 2) \div (3,2)^2$ ✓

$= 40 \div 10,24 =$ **$3,9$ m/s^2** ✓

3. (instantaneous) speed after 20 m?

from the table above we can use u, s and t, hence: $s = \left\{\frac{u + v}{2}\right\} t$ ✓

$20 = (0 + v) \times 3,2$ ✓

$20 \div 3,2 = \frac{1}{2} \cdot (0 + v)$

$2 \times (20 \div 3,2) = 40/3,2 =$ **12,5 m/s = speed after 20 m** ✓✓

4. Will he run faster than 10,8 s?

I. he covered the first 20 m in 3,2 s.

II. 80 m are left to run at 12,5 m/s: $v = s/t \quad \therefore$ time = s/v ✓

substitution: t = 80/12,5 = **6,4 s** time for 80 m ✓✓

total time: 3,2 s + 6,4 s = 9,6 s ✓✓

Which is much faster than his previous best.

(In fact it is a new world record. Let's applaud Mandla and also let's learn from this that the examiners are sometimes over ambitious in setting questions which can be quite misleading when you think about the actual world record time for a 100m sprint!)

Q11 1 a) average speed between Joburg and Harrismith in km/hr:

ave. speed = $\frac{\text{distance}}{\text{time}}$ = 240 km ÷ 3 hr = **80 km/hr** ✓✓✓

b) in m/s: 80 km/hr = 80 x 10m/36 s = 800 ÷ 36 = **22 m/s** ✓✓✓

2) 3hr + ½ hr + 2 hr = 5½ hr after leaving J. she is in Mooi River ✓

and has covered 240km + 200km = 440 km; ✓

Hence distance from Mooi to Durban = 600 km – 440 km = 160 km ✓

Time for 160 km at 80 km/hr: time = distance/speed = 160 ÷ 80 = 2hr ✓✓

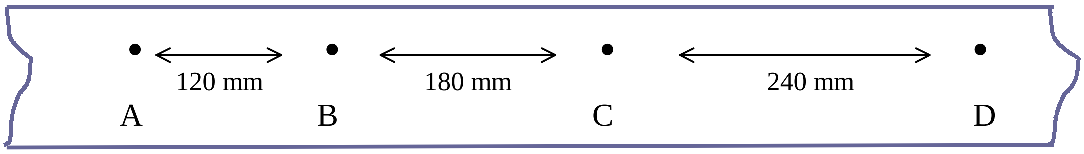
Arrival in Durban: 5½ hr + 2 hr = 7½ hr after leaving J.

Hence **arrival time = 01.30 pm** ✓

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 ✓
$\therefore$ **Time** = 10 x 0,02 s = **<u>0,2 s</u>** ✓

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



i) average speed AB:

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

ii) average speed BC:

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

iii) average speed CD:

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

1.3 average acceleration AC:

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

✓✓✓ (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:

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

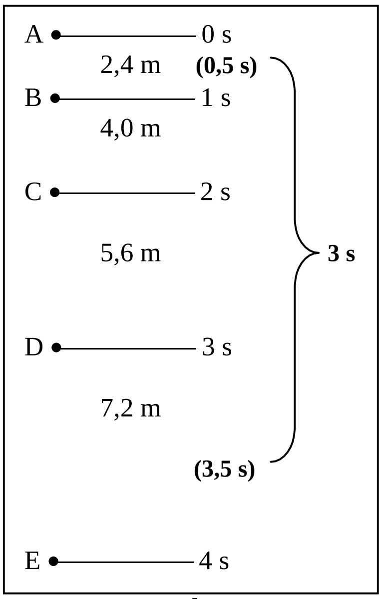
1.4 The trolley moves with constant acceleration. ✓✓

Q2

(You might think that this problem is not a ticker tape problem because there is no tape provided to be investigated. However, the data given suggests that applying the concept of ticker tapes is the most convenient method and yields the best result.)

a) i) average velocity during the first second:

$$\text{average velocity} = \frac{\text{displacement}}{\text{time}} = \frac{2{,}4\text{ m}}{1\text{ s}} = \mathbf{2{,}4\ m/s}\text{ (down)}$$



ii) average velocity during fourth second:

$$\text{average velocity} = \frac{\text{displacement}}{\text{time}} = \frac{7{,}2\text{ m}}{1\text{ s}} = \mathbf{7{,}2\ m/s}\text{ (down)}$$

Remember:
The average velocity between 0 seconds and 1 second gives the instantaneous velocity at time t = 0,5 s.
Accordingly, the average velocity during the fourth second gives the instantaneous velocity at time t = 3,5 s.

b) Acceleration due to gravity on the moon:

$$\text{acceleration} = \frac{\Delta\text{ velocity}}{\Delta\text{ time}} = \frac{v\ -\ u}{\Delta\text{ t}} = \frac{(7{,}2 - 2{,}4)\text{ m/s}}{(3{,}5 - 0{,}5)\text{ s}} = \frac{4{,}8\text{ m/s}}{3\text{ s}} = \mathbf{1{,}6\ m/s^2} \Downarrow$$

<u>**acceleration = 1,6 m/s^2** ⇩ (down)</u>

Answers to Multiple Choice Questions:

Worksheet 1		Worksheet 2		Worksheet 3		Worksheet 4	
1	B	1	A	1	C	1	D
2	C	2	D	2	B	2	B
3	D	3	C	3	D	3	C
4	D	4	D	4	A		
5	A	5	B	5	C		
6	A	6	A	6	D		
7	B	7	A	7	D		
8	D	8	B	8	D		
9	D	9	C	9	C		
10	C	10	C	10	A		