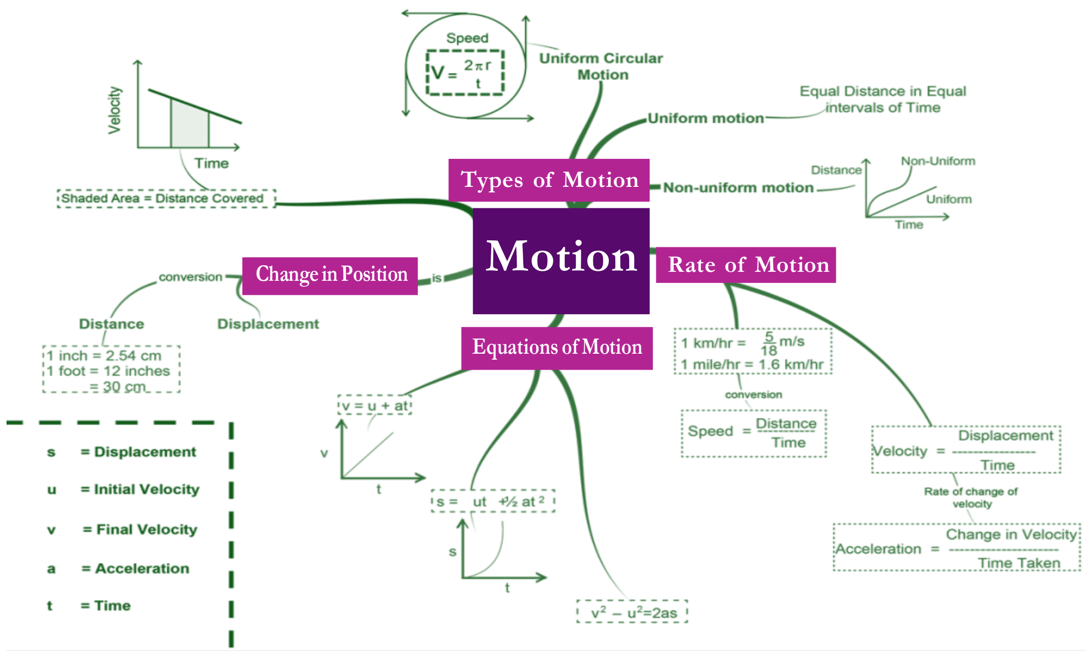
1 MOTION

Evangelista Torricelli was an Italian physicist and mathematician, best known for his invention of the barometer, but is also known for his advances in optics and work on the method of indivisibles.

Torricelli studied projectiles and how they traveled through the air. "Perhaps his most notable achievement in the field of projectiles was to establish for the first time the idea of an envelope: projectiles sent out at the same speed in all directions trace out parabolas which are all tangent to a common paraboloid. This envelope became known as the parabola di sicurezza (safety parabola)”.

CONCEPT MAP



Concept 1

Introduction:

The branch of physics that is concerned about motion is called kinematics. In our day-to-day life experience, we recognize that motion represents continuous change in position of an object when we compare to a non-moving object or reference point. In fact, the whole world and everything in it are moving. Even stationary things, such as trees, buildings and mountains, are also moving because the Earth itself is moving around the Sun, the solar system is orbiting around the centre.

Rest and Motion:

In physics, rest refers to an object's state when it doesn't change its position relative to its surroundings, while motion describes an object's change in position over time.

Reference Frames:

In physics, the concept of reference frame is very important and must be understood clearly and remembered forever. There are two types of reference frames:

(i) Inertial reference frame and (ii) Non-inertial reference frame

Inertial reference frame:

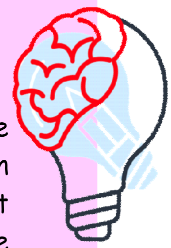
Let us assume that there is a point (at the centre of the Universe), which is not moving at all, no matter from where we look at it. Such a point is said to be at absolute rest. A reference frame situated at this point is an inertial reference frame. Any other reference frame that is moving at a constant velocity with respect to such a point (at absolute rest) is also an inertial reference frame. In other words, we say that a reference frame that is not accelerated is an inertial reference frame.

Non-inertial reference frame:

All other reference frames, except the one defined previously, are non-inertial reference frames. In other words, reference frames that are accelerated are non-inertial reference frames. A reference frame situated on the Earth or any other planet is a non-inertial reference frame as it is accelerated.

Knowledge Box

Galileo Galilei was one of the first scientists to study motion in detail. He discovered that objects fall at the same rate regardless of their mass when air resistance is negligible.



For example, a ball dropped towards the ground does not go exactly straight down because the Earth is rotating, which means the frame of reference of an observer on the Earth is not inertial.

Distance:

Distance is the total length of the path covered by an object, irrespective of direction. Distance is a scalar quantity and its SI unit is metre (m).

Displacement:

The shortest distance (path) covered by an object in the specified direction is called "Displacement". It is a vector. SI unit of displacement is metre (m).

Speed:

Speed is the rate at which an object covers distance. It is a scalar quantity that represents how fast an object is moving regardless of its direction.

$$\text{Speed}=\frac{\text{Distance}}{\text{Time}}$$

Its SI unit is m/s. It is a scalar quantity. It is denoted by v.

Average Speed:

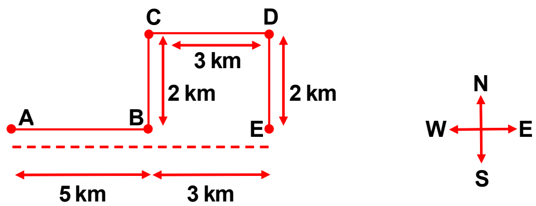
While travelling in a car or bus, we might have noticed that one cannot maintain a constant speed because of the holes or depressions on the road, the traffic and the red lights. One has to slow down or stop the car. Thus, the speed of the car or the bus is usually not maintained at a particular value. It keeps changing. For example, if a car takes 3 h to travel 75 km, the average speed of the car is $\frac{75}{3} = 25\text{km}$ per hour. Although the average speed of the car is 25 km per hour, it does not mean that the car is always moving at this speed for all the time.

The average speed of an object in a time interval is equal to the total distance travelled divided by the time interval.

$$\text{Average speed}=\frac{\text{Distance travelled}}{\text{Time interval}}$$

Velocity:

We have understood various speeds in the previous section, it is now easy to understand the concept of velocity. Speed is a scalar quantity, and velocity is the vector quantity. Thus, the velocity always includes a sense of direction.



In the above diagram, a car makes its journey from point A to B which is 5 km east, from B to C which is 2 km north, from C to D which is 3 km east and then from D to E which is 2 km south, then it reached a point E which is 8 km (=5 km + 3 km) from A towards east in a particular time interval. So, we can say that the change of position is 8 km from A towards east, which is the total displacement of the car in this case. However, the total path travelled by car which is (5+2+3+2)km = 12 km, it is called the distance.

Let's assume that the total time taken for the entire journey is 4h.
So, we can say that the rate of change in the displacement of a body is called the velocity.

$$\text{Velocity}=\frac{\text{Displacement}}{\text{Time interval}}$$

Now, we will define the average velocity for the entire journey as

$$\text{Average velocity}=\frac{\text{Change in position (displacement)}}{\text{Time}}$$

$$\text{Average velocity}=\frac{8 \text{ km towards east}}{4 \text{ h}}$$

Average velocity=2 km/h towards east

The velocity is denoted by v, and the SI unit of velocity m/s. Since the velocity involves a sense of direction, it is a vector quantity.

In the above example, if we divide the total distance, which is 12 km, by the total time, we will get the average speed = 3 km/h.

Misconception :

Misconception: If an object is at rest, no forces are acting on it.
Correction: Even at rest, forces such as gravity and normal force act on an object to balance it.

Uniform motion:

If the magnitude and the direction of motion of a body do not change with time, then we say that the velocity is uniform. Thus, a body has a uniform velocity if it travels in a straight line and moves equal displacements in equal intervals of time, no matter how small these time intervals be.

Non-uniform motion:

If the velocity of a moving body does not remain constant in a given time interval, it is known as non-uniform velocity.

We can also conclude that the velocity of a body can change in three ways: (i) by changing the speed of the body, (ii) by keeping the speed constant but changing the direction and (iii) by changing the speed and the direction. Suppose a car is moving on a circular road at a constant speed. Now, though the speed of the car is constant, its velocity is not uniform because the direction of the car is changing continuously.

Acceleration:

The rate of change of velocity is known as acceleration. It is a vector and acts along the direction of change of velocity.

$$\text{Acceleration}=\frac{\text{Final velocity-Initial velocity}}{\text{Time taken}}$$

Suppose the initial velocity of a body is u and it changes to a final velocity v in time t, then

$\therefore$ Acceleration, $a=\frac{v-u}{t}$

The SI unit of acceleration is m/s^2.

CLASSROOM DISCUSSION QUESTIONS
CDQ 01

1. Which of the following best defines the term "relative"?

(A) Constant

(B) Absolute

(C) Comparative

(D) Static

2. When is a body said to be in motion?

(A) When its position is fixed relative to an observer

(B) When its position changes continuously with time relative to an observer

(C) When its position remains constant

(D) None

3. What is distance?

(A) The shortest distance between two points

(B) The change in position of an object

(C) The length of the path traversed by an object in a given time interval

(D) The displacement of an object

4. Which of the following is a scalar quantity?

(A) Displacement (B) Velocity

(C) Distance (D) Acceleration

5. What is average velocity?

(A) The speed of an object at any given instant

(B) The change in position of an object over a specific time period

(C) The displacement of an object per unit time

(D) The distance covered by an object per unit time

6. What is instantaneous speed?

(A) The speed of an object over a long time period

(B) The average speed of an object

(C) The speed of an object at any given moment

(D) The maximum speed of an object

7. How is velocity different from speed?

(A) Velocity is a scalar quantity, while speed is a vector quantity

(B) Velocity includes direction, while speed does not

(C) Velocity is constant, while speed varies

(D) Velocity is the same as distance

MARK YOUR ANSWERS WITH PEN ONLY. Time Taken ☐ Minutes

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Concept 2

Equations of motion:

The relation among velocity, distance, time and acceleration is called equations of motion. It is also known as kinematic equations.

The motion of an object moving at uniform acceleration can be described with the help of three equations, namely

(i) $v = u + at$ (the first equation of motion)

(ii) $s = ut + \frac{1}{2}at^2$ (the second equation of motion)

(iii) $2as = v^2 - u^2$ (the third equation of motion)

Here, u = initial velocity, v = final velocity, a = acceleration, s = displacement and t = time interval

Linear Motion:

This motion is a one dimensional motion that takes place in a straight line. For example, a train running on a track.

Linear motion of a body can be studied with the help of the following graphs:

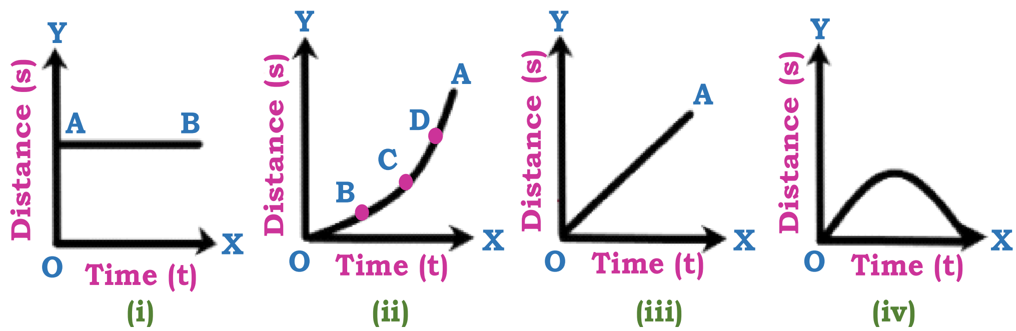
(i) Distance - Time Graph or displacement - time graph

(ii) Velocity - Time Graph

(iii) Acceleration - Time Graph

(I) Distance - Time Graph

In the distance - time graph, the time is taken on the X-axis and the distance covered by the body is taken on the Y-axis.



Slope of Distance - Time graph gives Speed

Slope of the Displacement - Time Graph Gives the Velocity.

(Note: In the place distance if we take displacement, the graphs can be represented as displacement-time graphs)

(a) Graph (i) shows at t = 0, the particle at point A, and with an increase in time, the distance is not changing. Thus, the graph line is parallel to the time axis, and the slope of the graph is zero. So, the speed of the particle is zero. It means the body is at rest.

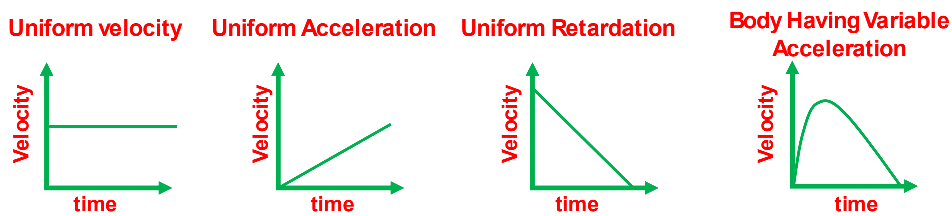
(b) In graph (ii), OA is curved line, the slope of a graph is a variable as we move from O to A, i.e., at B, C and D, the slope of the graph gradually increases, so the speed of the particle also increases. Thus, the particle is accelerating.

(c) In graph (iii), line OA has a definite constant slope. Hence, the speed of the body is a non-zero constant.

(d) Graph (iii) represents the distance-time graph for retarded motion.

Velocity - Time Graph:

In the velocity-time graph, the time is taken on the X-axis and the velocity of the body is taken on the Y-axis.



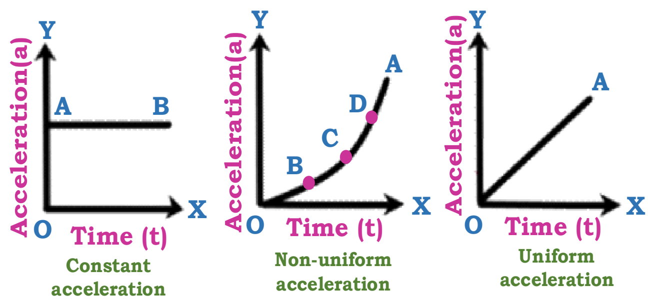
Acceleration - Time Graph:

In the acceleration-time graph, the time is taken on the X-axis and the acceleration of the body is taken on the Y-axis.

It is possible that an object or a body can have variable acceleration. If the object accelerates, its velocity changes. Suppose a car starts with a positive acceleration, and the acceleration is more initially, goes on decreasing and finally becomes zero. What does it mean? Initially, the velocity will increase at a faster rate, and finally, when the acceleration is zero, the speed will be maximum and constant.

Fun Facts

When you throw a ball straight up, its acceleration is always $-9.8\ m/s^2$, even at the highest point!



CLASSROOM DISCUSSION QUESTIONS

CDQ 02

1. Which of the following is the correct form of the first equation of motion?

(A) $s = ut + \frac{1}{2}at^2$

(B) v =u+at

(C) $v^2 = u^2 + 2as$

(D) None

2. If a body moves along a straight line with constant speed, what will its acceleration be?

(A) Positive

(B) Negative

(C) Zero

(D) Cannot be determined

3. In a velocity-time graph, a straight line parallel to the time axis indicates:

(A) Constant acceleration

(B) Constant velocity

(C) Increasing velocity

(D) Decreasing velocity

4. What is the SI unit of acceleration?

(A) m/s (B) m/s^2

(C) km/h^2 (D) m^2/s

5. What is the shape of the velocity-time graph for uniformly accelerated motion?

(A) Curved line

(B) Horizontal line

(C) Straight line inclined to the time axis

(D) Vertical line

6. What does the slope of a velocity-time graph indicate?

(A) Velocity (B) Time

(C) Acceleration (D) Distance

7. Which of the following describes uniform motion in a distance-time graph?

(A) A curved line

(B) A horizontal line

(C) A straight line with a constant slope

(D) A vertical line

8. A car accelerates from 10 m/s to 30 m/s in 5 seconds. What is its acceleration?

(A) 2 m/s^2 (B) 3 m/s^2

(C) 4 m/s^2 (D) 5 m/s^2

MARK YOUR ANSWERS WITH PEN ONLY. Time Taken ☐ Minutes

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6 Ⓐ Ⓑ Ⓒ Ⓓ	7 Ⓐ Ⓑ Ⓒ Ⓓ	8 Ⓐ Ⓑ Ⓒ Ⓓ	9 Ⓐ Ⓑ Ⓒ Ⓓ	10 Ⓐ Ⓑ Ⓒ Ⓓ

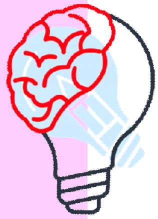
Concept 3

Acceleration Due to Gravity(g):

When a body falls freely toward the center of the Earth, it experiences a uniform acceleration called acceleration due to gravity (denoted as g).

This acceleration is caused by the gravitational force exerted by the Earth on the body.

Knowledge Box



Acceleration due to gravity g on Earth is approximately 9.8 m/s^2. It is different on other heavenly bodies:

Moon: 1.67 m/s^2

Mars: 3.71 m/s^2

Jupiter: 24.79 m/s^2

Properties of Acceleration Due to Gravity (g):

1. Constant for all Bodies at a Given Place:

The value of g is the same for all objects, regardless of their size, shape, material, or whether they are hollow or solid.

2. Independence from Mass:

In the absence of air resistance, all objects (whether heavy or light) fall with the same acceleration when dropped from the same height.

3. Variation of g on Earth's Surface:

g varies from place to place on the Earth's surface:

It is maximum at the poles ($\approx$9.83 m/s^2).

It is minimum at the equator ($\approx$9.78 m/s^2).

The average value of g on Earth is 9.8 m/s^2.

4. Value of g on Other Celestial Bodies:

On the Moon: 1.67 m/s^2 (approximately 1/6th of Earth's gravity).

On the Sun: 27.1 m/s^2 (about 2.76 times Earth's gravity).

5. Direction of g:

The acceleration due to gravity always acts downward toward the center of the Earth.

When a body falls toward the Earth, g is positive (velocity increases).

When a body is projected upwards, g is negative (velocity decreases).

6. g at the Center of the Earth:

At the center of the Earth, g = 0, meaning there is no acceleration due to gravity.

Equations of Motion for Freely Falling Body:

When a body is dropped from rest and falls freely under gravity (neglecting air resistance), the initial velocity is u = 0 and acceleration is a = g. The equations of motion modify as follows:

1. Velocity after time t: $v = u + at \Rightarrow v = gt$

2. Distance traveled in time t: $s = ut + \frac{1}{2}at^2 \Rightarrow s = \frac{1}{2}gt^2$

3. Velocity-distance relation: $v^2 - u^2 = 2as \Rightarrow v^2 = 2gs$

4. Distance traveled in the nth second: $s_n = u + a\left(n - \frac{1}{2}\right) \Rightarrow s_n = g\left(n - \frac{1}{2}\right)$

Important Notes on Free Fall:

- The ratio of distances traveled in 1s, 2s, 3s, 4s, ... follows 1:4:9:16 and so on.
- The ratio of distances traveled in successive seconds follows 1:3:5:7 and so on.
- In uniform acceleration, the distance covered in each second increases in proportion to acceleration g.

Equations of Motion for a Vertically Projected Upwards Body:

When a body is projected upwards with an initial velocity u, it moves against gravity (a = –g). The equations of motion become:

1. Velocity after time t: $v = u + at \Rightarrow v = u - gt$

2. Height reached in time t: $s = ut + \frac{1}{2}at^2 \Rightarrow s = ut - \frac{1}{2}gt^2$

3. Velocity-height relation: $v^2 - u^2 = 2as \Rightarrow v^2 = u^2 - 2gs$

4. Distance traveled in the nth second: $s_n = u + a\left(n - \frac{1}{2}\right) \Rightarrow s_n = u - g\left(n - \frac{1}{2}\right)$

Misconception :

Misconception: Heavier objects fall faster than lighter objects.

Correction: Without air resistance, all objects fall at the same rate!

Key points on Free Fall and Upward Motion:

- In free fall, the velocity increases over time due to gravity.
- In upward motion, the velocity decreases due to gravity until it reaches zero at the highest point.
- Time taken to reach maximum height = u/g.
- Total time for upward and downward journey = 2u/g.

CLASSROOM DISCUSSION QUESTIONS

CDQ 03

1. **What is the value of acceleration due to gravity on the surface of the moon?**
   (A) 9.8 m/s^2 (B) 1.67 m/s^2
   (C) 27.4 m/s^2 (D) 9.78 m/s^2

2. **Which of the following statements is true about the acceleration due to gravity (g)?**
   (A) It is dependent on the material of the falling body.
   (B) It is constant at all places on the Earth's surface.
   (C) It has a maximum value at the equator.
   (D) It is independent of the shape and size of the body.

3. **If a body is projected upwards, how does its velocity change according to the acceleration due to gravity?**
   (A) Increases and g is positive.
   (B) Decreases and g is negative.
   (C) Remains constant and g is zero.
   (D) Increases and g is negative.

4. **What is the average value of acceleration due to gravity on the surface of the Earth?**
   (A) 9.78 m/s^2 (B) 9.83 m/s^2
   (C) 1.67 m/s^2 (D) 9.8 m/s^2

5. **Which equation represents the distances traveled by a freely falling body in time *t*?**
   (A) $s = ut + \frac{1}{2}gt^2$ (B) $s = \frac{1}{2}gt^2$
   (C) $s = v^2 - u^2$ (D) $ut - \frac{1}{2}gt^2$

6. **Which of the following represents the correct value of *g* at the poles of the Earth?**
   (A) 9.8 m/s^2 (B) 9.78 m/s^2
   (C) 1.67 m/s^2 (D) 9.83 m/s^2

7. **For a body projected vertically upwards with an initial velocity *u*, which equation gives its final velocity *v* after time *t*?**
   (A) $v=u+gt$ (B) $v=u-gt$
   (C) $v=u+at$ (D) $v=u-at$

8. **What is the ratio of distances traveled in successive seconds by a freely falling body?**
   (A) 1:2:3:4 (B) 1:4:9:16
   (C) 1:3:5:7 (D) 1:2:4:8

MARK YOUR ANSWERS WITH PEN ONLY. Time Taken ____ Minutes

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6 Ⓐ Ⓑ Ⓒ Ⓓ	7 Ⓐ Ⓑ Ⓒ Ⓓ	8 Ⓐ Ⓑ Ⓒ Ⓓ	9 Ⓐ Ⓑ Ⓒ Ⓓ	10 Ⓐ Ⓑ Ⓒ Ⓓ

Concept 4

Motion Parameters of a Body Projected Vertically Upwards:

Maximum height:

For a body projected upwards, the maximum vertical displacement from ground about which its velocity is zero is called its maximum height.

Let a body be projected vertically upwards with an initial velocity 'u'.

Initial velocity, u = u m/s

Final velocity, v = 0

Acceleration due to gravity = – g m/s^2

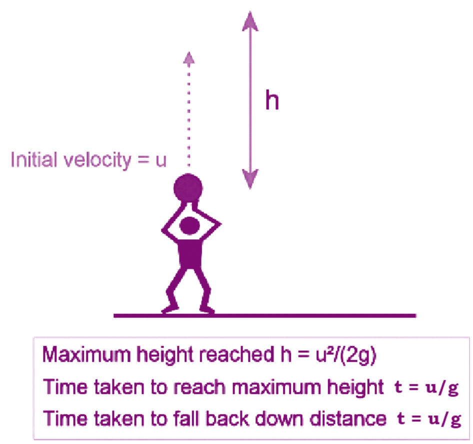
Let the maximum height reached by the body be 'H_{max}'.

Then using the formula

$v^2 - u^2 = 2gh.$

$\Rightarrow 0 - u^2 = -2gH_{max}$

$\Rightarrow H_{max} = \frac{u^2}{2g}$



Time of ascent:

For a body projected upwards the time to reach the maximum height is called time of ascent.

Let a body be projected vertically upwards with an initial velocity 'u'.

Initial velocity = u m/s

Acceleration of the body = –g m/s^2

Final velocity of the body = v = 0

Let the time of ascent be 't_a'

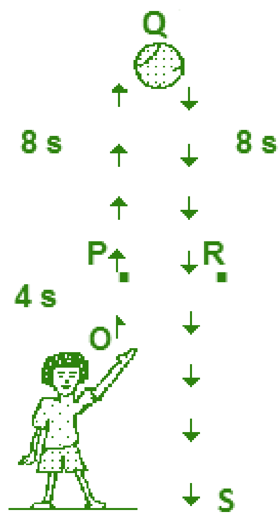
Now using formula

$v = u - gt$

$\Rightarrow 0 = u - gt_a$

$\Rightarrow u = gt_a$

$\Rightarrow t_a = \frac{u}{g}$



Time of descent:

For a body projected upwards, the time to travel from maximum height to the point of projection on ground is called time of descent.

Expression:

Let a body be projected vertically upwards with an initial velocity 'u'.

Step 1: For upward motion

We know that

$$v^2 - u^2 = 2gh.$$

$$0 - u^2 = -2gH_{max}$$

$$H_{max} = \frac{u^2}{2g}$$

Step 2: For downward motion

We know that

$$s = ut + \frac{1}{2}at^2 \qquad \Rightarrow \qquad h = \frac{1}{2}gt^2$$

For a body projected upwards at maximum height the velocity becomes zero. This will be considered as initial velocity during downward motion.

Here initial velocity = 0, a = + g, t = t_d, s = H_{max}.

$$H_{max} = 0 + \frac{1}{2}gt_d^{\ 2}$$

$$\frac{u^2}{2g} = \frac{1}{2}gt_d^{\ 2}$$

$$t_d = \frac{u}{g}$$

Time of flight:

For a body projected vertically upwards the sum of time of ascent and time of descent is called time of flight (T). It is the total time for which the body remains in air.

Time of flight = Time of ascent + Time of descent

It is given by $T = t_a + t_d \quad = \frac{u}{g} + \frac{u}{g} = \frac{2u}{g}$

CLASSROOM DISCUSSION QUESTIONS

CDQ 04

1. What is the time of ascent t_a for a body projected vertically upwards with an initial velocity *u*?

(A) $\frac{u}{2g}$ (B) $\frac{u}{g}$

(C) $\frac{2u}{g}$ (D) $\frac{u^2}{g}$

2. For a body projected vertically upwards, what is the time of descent t_d from the maximum height back to the ground?

(A) $\frac{u}{2g}$ (B) $\frac{u}{g}$

(C) $\frac{2u}{g}$ (D) $\frac{u^2}{2g}$

3. If a body is projected vertically upwards, what is its velocity at the maximum height?

(A) u (B) u/2

(C) 0 (D) –u

4. What is the formula for the time of flight *T* for a body projected vertically upwards with an initial velocity *u*?

(A) $\frac{2u}{g}$ (B) $\frac{u}{g}$ (C) $\frac{u^2}{2g}$ (D) $\frac{u^2}{g}$

5. A body is projected vertically upwards with an initial velocity of 20 m/s. What is the time of ascent? (Take $g=9.8 m/s^2$)

(A) 1.02 s (B) 2.04 s

(C) 4.08 s (D) 10.2 s

6. What is the total time of flight for a body projected vertically upwards with an initial velocity of 30 m/s? (Take $g=9.8 m/s^2$)

(A) 3.06 s (B) 6.12 s

(C) 9.18 s (D) 12.24 s

7. If a body is projected vertically upwards with an initial velocity *u*, what is the expression for its velocity *v* after time *t* during ascent?

(A) v=u+gt (B) v=u–gt

(C) v=u+2gt (D) v=u–2gt

MARK YOUR ANSWERS WITH PEN ONLY. Time Taken ☐ Minutes

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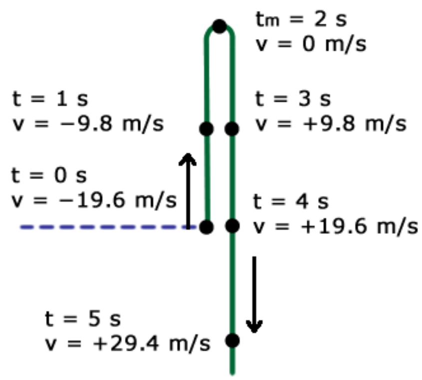
Concept 5

Velocity of the body on reaching the point of projection:

Let a body be projected vertically upwards with an initial velocity 'u'.

The body reaches the point of projection once again after the time of flight (T).



We know that

$v = u + at$

Here $a = -g$; $t = T = 2u / g$; $v = V_{striking}$

$\Rightarrow \quad V_{striking} = u - gT$

$\Rightarrow \quad V_{striking} = u - g\,(2u / g)$

$\Rightarrow \quad V_{striking} = u - 2u$

$\Rightarrow \quad V_{striking} = -u$

So the body reaches the point of projection with the same speed of projection but in opposite direction.

(-ve sign gives that object is moving opposite direction to the projection).

Velocity at a given height:

Let a body be projected vertically upwards with an initial velocity u.

The body reaches a height 'h' after certain time 't'.

We know that

$v^2 = u^2 + 2as$

Here $v = V$; $u = u$; $a = -g$; $s = h$

$\Rightarrow \quad v^2 = u^2 - 2gh$

$\Rightarrow \quad v = \sqrt{u^2 - 2gh}$

Note:

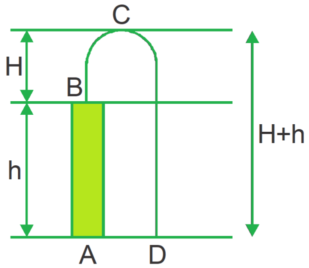
1. A body can have zero velocity and non zero acceleration at an instant. For example, at highest point of vertically projected body the velocity vector is null vector but acceleration vector is vertically downwards.
2. Distance covered by the body projected vertically up in the 1st second of its upward journey is equal to the distance covered by it in the last second of its downward journey.

$$s = u - g/2$$

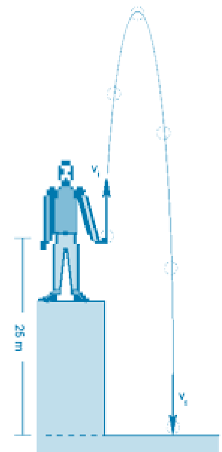
3. Distance covered by the body projected vertically up in the last second of its upward journey is equal to the distance covered by it in the 1st second of its downward journey.

$$s = g/2$$

Motion of a body thrown vertically up from top of a tower:



AB is a tower of height h. A body is projected vertically upwards with an initial velocity 'u' from the top 'B' of the tower. The body travels upwards, reaches the highest point C and starts falling downwards there after. Finally the body reaches the point D lying in the horizontal plane passing through foot of the tower. Here the direction of projection (upwards) is considered as positive and the opposite direction (i.e., downwards) is taken negative.



The upward displacement of the body; BC = +H

The downward displacement of the body;

CD = – (h+H)

The net displacement of the body;

BD = +H –(h+H) = – h

The total time of travel from B to D through C = t (say)

For the motion of the body

Displacement (s) = –h

Acceleration (a) = –g (Starting upwards)

Time of travel (t) = t

Initial velocity (u) = u

From the equation of motion $s = ut + \frac{1}{2}at^2$

$\Rightarrow -h = ut - \frac{1}{2}gt^2$ $\quad\quad \Rightarrow h = -ut + \frac{1}{2}gt^2$

The height of tower is given by $h = \frac{1}{2}gt^2 - ut$.

Note:

This is a quadratic equation in time.

Comparing with the standard quadratic equation $ax^2 + bx + c = 0$

We get $t = \frac{u \pm \sqrt{u^2 + 2gh}}{g}$

CLASSROOM DISCUSSION QUESTIONS

CDQ 05

1. What is the formula for the velocity *v* at a given height *h* for a body projected vertically upwards with an initial velocity *u*?

(A) $v=\sqrt{u^2+2gh}$ (B) $v=\sqrt{u^2-2gh}$

(C) $v=\sqrt{u^2+gh}$ (D) $v=\sqrt{u^2-gh}$

2. If a body is projected vertically upwards from the top of a tower of height *h* with an initial velocity *u*, what is the net displacement of the body when it reaches the ground?

(A) h (B) –h (C) u (D) –u

3. A body projected vertically upwards from the top of a tower with an initial velocity *u* reaches the highest point C and then falls down to the ground. What is the total time of travel from the top of the tower to the ground?

(A) $\frac{u}{g}$ (B) $\frac{2u}{g}$

(C) $\sqrt{\frac{2h}{g}}$ (D) $t=\frac{u}{g}+\sqrt{\frac{2h}{g}}$

4. What is the acceleration of a body at its highest point when projected vertically upwards?

(A) 0 (B) –g

(C) g (D) 2g

5. What is the distance covered by the body projected vertically upwards in the first second of its upward journey?

(A) $u-\frac{g}{2}$ (B) u-g

(C) $\frac{u}{2}$ (D) u+g

6. What is the displacement of a body projected vertically upwards from a height *h* with an initial velocity *u* when it reaches back to the height *h* on its way down?

(A) 0 (B) h

(C) –h (D) –u

7. What is the net displacement of the body thrown vertically upwards from the top of a tower after reaching the highest point and then falling back to the ground?

(A) –H (B) H+h

(C) –h (D) h–H

MARK YOUR ANSWERS WITH PEN ONLY. Time Taken ☐ Minutes

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

C.D.F. (Concepts, Definitions and Formulae)

1. We know that all objects, when dropped, fall towards the Earth with constant acceleration due to gravitational force of the earth. This is called acceleration due to gravity (g).
2. Objects in motion under the influence of gravity are said to be in free fall.
3. **Equations of motion for freely falling body:**
   (For a freely falling bodies u = 0 and a = +g)
   $v = u + g t \Rightarrow \quad v = gt$
   $h = ut + \frac{1}{2}gt^2 \quad \Rightarrow \quad h = \frac{1}{2}gt^2$
   $v^2 - u^2 = 2gh \quad \Rightarrow \quad v^2 = 2gh$
4. **Equations of Motion of an object vertically Projected Upwards from the Ground:**
   (For a vertical projected bodies v = 0 on reaching maximum height and a=-g)
   $v = u - gt \quad \Rightarrow \quad u = gt$
   $h = ut - \frac{1}{2}gt^2$
   $v^2 - u^2 = -2gh \quad \Rightarrow \quad u^2 = 2gh$
5. When a body is projected vertically upwards with an initial velocity 'u'; the maximum height reached by the body is given by $h = \frac{u^2}{2g}$
6. Time of ascent of a vertically projected body is given by $t_a = \frac{u}{g}$
7. Time of descent of a vertically projected body is given by $t_d = \sqrt{\frac{2h}{g}} = \frac{u}{g}$
8. Time of flight of a vertically projected body is given by $t_a = \frac{2u}{g}$
9. Velocity at a given height for a vertically projected body is given by $v = \pm\sqrt{u^2 - 2gh}$
10. For a freely falling body ratio of the distances travelled after 1st second, next 1 second, next 1 second, ... is 1 : 3 : 5 : ....

Advanced Worksheet

LEVEL 1

Single Correct Answer Type (S.C.A.T.):

1. What type of motion is exhibited by a freely falling body?

(A) Uniform motion

(B) Non-uniform motion

(C) Circular motion

(D) Both uniform and non-uniform motion

2. The average speed of a moving object during a given interval of time is

(A) The magnitude of its average velocity over the interval

(B) The distance covered during the time interval divided by the time interval

(C) One-half its speed at the end of the interval

(D) Its acceleration multiplied by the time interval

3. Retardation is:

(A) Negative acceleration

(B) Positive acceleration

(C) Uniform acceleration

(D) Variable acceleration

4. When an object is moving with uniform velocity, what is its acceleration?

(A) Zero

(B) Uniform

(C) Non-uniform

(D) Negative

5. Which pair of variable defines motion?

(A) Speed and distance

(B) Time and momentum

(C) Change of position and passage of time

(D) Speed and passage of time

6. Which two fundamental properties are used to describe motion?

(A) Mass and distance

(B) Length and time

(C) Speed and time

(D) Distance and speed

7. Name the quantity that is defined as the rate of change of displacement.

(A) Velocity

(B) Acceleration

(C) Distance

(D) Speed

8. A body moving along a straight line at 20 m/s undergoes an acceleration of 4 m/s². After 2 seconds its speed will be:

(A) 8 m/s

(B) 12 m/s

(C) 16 m/s

(D) 28 m/s

9. Negative acceleration means an object is moving with:

(A) Increasing speed

(B) Decreasing speed

(C) Uniform speed

(D) Constant speed

10. Motion along a straight line is called:

(A) Rectilinear motion

(B) Circular motion

(C) Oscillatory motion

(D) Parabolic

11. The physical quantity describing motion and whose measure is the division of distance travelled and the time taken to travel that distance is:

(A) Speed

(B) Mass

(C) Weight

(D) Displacement

12. Two trains travelling on the same track are approaching to each other with equal speeds of 40 m/s. The drivers of the trains begin to decelerate simultaneously when just 1 km apart. Assuming decelerations to be uniform and equal, the value of the deceleration to barely avoid collision should be:

(A) 0.8 m/s^2

(B) 1.6 m/s^2

(C) 11.0 m/s^2

(D) 11.8 m/s^2

13. A student goes from his house to his friend's house with speed v_1. Finding the door of his friend's house closed, he returns back to his own house with the speed v_2. The average speed will be:

(A) $\frac{v_1 + v_2}{2}$

(B) $\sqrt{v_1 v_2}$

(C) $\frac{2v_1 v_2}{v_1 + v_2}$

(D) $v_1 v_2$

14. On a 120 km track, a train travels the first 30 km at a uniform speed of 30 km/h. How fast must the train travel the next 90 km so as to average 60 km/h for the entire trip?

(A) 120 km/h

(B) 90 km/h

(C) 30 km/h

(D) 60 km/h

15. The distance (s) in meters travelled by a particle is related to time (t) in seconds by the equation of motion $s = 10t+4t^2$. What is the initial velocity of the body?

(A) 10 m/s

(B) 6 m/s

(C) 4 m/s

(D) 10 m/s^2

16. A cyclist goes around a circular track once every 2 minutes. If the radius of the circular track is 105 meters, what will be his speed? (taken $\pi = \frac{22}{7}$)

(A) 2.3 m/s

(B) 3.5 m/s

(C) 4.5 m/s

(D) 5.5 m/s

17. A body is dropped from a height of 19.6 m. After falling through 4.9 m, the gravity ceases to act and the body falls down with constant speed. The ratio of times of fall with gravity and without gravity (gravity ceases means, there is no more acceleration due to gravity)

(A) 1: 2 (B) 2: 3

(C) 2: 1 (D) 3: 2

18. A food packet is released from a helicopter which is rising at 4 ms^{-1}. Then velocity of the packet after 2 seconds is

(A) 15.6 ms^{-1}up

(B) 15.6ms^{-1} down

(C) 17.6 ms^{-1} up

(D) 17.6 ms^{-1}down

19. A boy sees a ball going up and then back down through a window of 2.45 m high. If the total time the ball is in sight for up and down motion is 1 sec. The height above the window that the ball rises is

(A) 0.98 m

(B) 0.49 m

(C) 0.245 m

(D) 0.306m

20. A ball thrown up vertically with an initial speed of 20ms^{-1}. When it has reached 3/4 of the maximum height, speed of that ball is (g = 10 ms^{-2})

(A) 10 m/s

(B) 5 m/s

(C) 15 m/s

(D) 20 m/s

21. From a balloon moving down at 10 ms^{-1} an object is dropped when it is at an altitude of 40m. The object strikes the ground with a velocity equal to (g = 10 ms^{-2})

(A) 20 ms^{-1}

(B) $10\sqrt{7}$ ms^{-1}

(C) 30 ms^{-1}

(D) 40 ms^{-1}

LEVEL 2

Multi Correct Answer Type (M.C.A.T.):

22. Which of the following statement is true?

(A) When a body moves along a circular path, then its direction of motion keeps changing continuously.

(B) The motion along a circular path is said to be accelerated.

(C) A force is needed to produce a circular motion.

(D) Displacement along a circular path is always zero.

23. If the displacement of a body is proportional to square of time then:

(A) The body moves with uniform velocity.

(B) The body moves with uniform acceleration.

(C) The body moves with increasing acceleration.

(D) The body moves with decreasing acceleration.

24. Which of the following is the example of non-uniform motion?

(A) Freely falling body.

(B) A train starting from the railway station.

(C) A car running at 10 m/s.

(D) A car moving with uniform acceleration.

25. Which of the following is the example of uniformly accelerated motion?

(A) Freely falling body.

(B) A train starting from the railway station.

(C) A car running at 10 m/s

(D) The motion of a ball rolling down an inclined plane.

26. An object while moving may not have:

(A) Variable speed but constant velocity.

(B) Variable velocity but constant speed.

(C) Non-zero acceleration but constant speed.

(D) Non-zero acceleration but constant velocity.

27. An athlete moves on a quarter circle of radius r in time t. Then

(A) The distance traversed by athlete is $\frac{\pi r}{2}$

(B) The displacement of athlete is $\frac{\pi r}{2}$

(C) The displacement of athlete is $r\sqrt{2}$

(D) The speed of athlete is $\frac{\pi r}{2t}$

28. An object may have

(A) Varying speed without having varying velocity.

(B) Varying velocity without having varying speed.

(C) Non zero acceleration having varying velocity.

(D) $a \neq 0$, without having varying speed.

29. Which of the following options are correct in the case of uniform circular motion?

(A) Velocity of the particle changes at every instant of time

(B) Speed of the particle changes at every instant of time

(C) Velocity is constant through out the motion

(D) Speed is constant through out the motion

30. Which of the following options are correct in the case of motion of ball on an inclined plane?

(A) Direction of the particle changes at every instant of time

(B) Speed of the particle changes at every instant of time

(C) Direction is same through out the motion

(D) Speed is constant through out the motion

31. Which of the following options are correct in the case of motion of an object thrown into air?

(A) Direction of the particle changes at every instant of time

(B) Speed of the particle changes at every instant of time

(C) Direction is same through out the motion

(D) Speed is constant through out the motion

Comprehension Passage Type (C.P.T.):

PASSAGE - I

A particle starts with an initial velocity 2.5 m/s along the positive x-direction and it accelerates uniformly at the rate 0.50 m/s².

32. What is the distance travelled by particle in the first two seconds?

(A) 5.0 m (B) 4.0 m

(C) 6.0 m (D) 9.0 m

33. How much time does the particle take to reach the velocity 7.5 m/s?

(A) 10 s (B) 0 s

(C) 6 s (D) 9 s

34. How much distance will the particle cover in reaching the velocity 7.5 m/s?

(A) 50 m (B) 40 m

(C) 30 m (D) 20 m

PASSAGE - II

A particle is moving in a circle of radius R with constant speed the time period of the particle is T seconds. Then

35. Displacement of the particle in a T/4 s is

(A) R (B) $\sqrt{2}R$

(C) R/2 (D) None

36. Average speed of the particle in T seconds is

(A) 0 (B) $\frac{2\pi R}{T}$

(C) $\frac{\pi R}{T}$ (D) None

37. Average velocity of the particle in T seconds is

(A) 0 (B) $\frac{2\pi R}{T}$

(C) $\frac{\pi R}{T}$ (D) None

LEVEL 3

Matrix Matching Type (M.M.T.):

SET-I

Column I

38. Straight line motion covering equal distance in equal intervals

39. Straight line motion with constant velocity

40. Straight line motion with equal velocity change in equal interval of time.

41. Straight line motion with equal velocity change in unequal intervals of time.

Column II

(A) Zero acceleration

(B) Always negative acceleration.

(C) Uniform acceleration

(D) Non-uniform acceleration.

SET-II

Column-I

42. First law of motion

43. Second law of motion

44. Third law of motion

45. Acceleration

Column-II

(A) $2as = v^2 - u^2$

(B) Uniformly accelerated body

(C) $a = (v-u) / t$

(D) $s = ut + \frac{1}{2} at^2$

(E) $v = u + at$

SET-III

Column-I	Column-II
46. Force	**(A)** m/s^2
47. Acceleration	**(B)** m/s
48. Speed	**(C)** Meter
49. Distance	**(D)** Newton
	(E) Scalar

Assertion Reason Type (A.R.T.):

(A) Both Assertion and Reason are Correct and reason is the correct explanation of assertion.

(B) Both Assertion and Reason are correct but reason is not the correct explanation of assertion.

(C) Assertion is correct but Reason is incorrect.

(D) Assertion is incorrect but Reason is correct.

50. Assertion (A): The average velocity of an object over an interval of time is either smaller than or equal to the average speed of the object over the same interval.

Reason (R): Velocity is a vector quantity and speed is a scalar quantity.

51. Assertion (A): A physical quantity can be called as a vector if its magnitude is zero.

Reason (R): A vector has both magnitude and direction.

52. Assertion (A): An object can have constant speed but variable velocity.

Reason (R): Speed is a scalar quantity but velocity is a vector quantity.

Statement Type (S.T.):

(A) Both statements I and II are true, and Statement II is the correct explanation of Statement I.

(B) Both statements I and II are true, but Statement II is NOT the correct explanation of Statement I.

(C) Statement I is true, but Statement II is false.

(D) Statement I is false, but Statement II is true.

53. Statement-I: The acceleration due to gravity on the Moon is about $\frac{1}{6}$th of that on Earth.

Statement-II: The weight of an object on the Moon is the same as its weight on Earth.

54. Statement-I: An object thrown upwards decelerates at a rate of g until it reaches the highest point.

Statement-II: At the highest point of its motion, the object's velocity is zero.

55. Statement-I: A freely falling object experiences uniform acceleration due to gravity.

Statement-II: The mass of the object affects the rate at which it falls under gravity.

Integer Type Questions (I.T.Q.):

56. A driver decreases the speed of a car from 25 m/s to 10 m/s in 5 seconds. Find the retardation of the car.

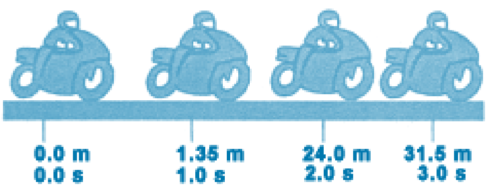
57. A body starting from rest travels with uniform acceleration. If it travels 100 m in 5 s, what is the value of acceleration?

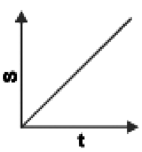
58. A motor cycle moving with a speed of 5 m/s is subjected to an acceleration of 0.2m/s^2, Calculate the speed of the motor cycle after 10 seconds.

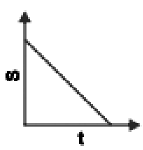
Figure Based Questions (F.B.Q.):

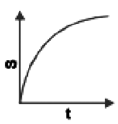
59. Motion of a motorcyclist is shown in the figure.

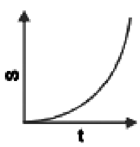
The distance - time graph for this motion is



(A) 

(B) 

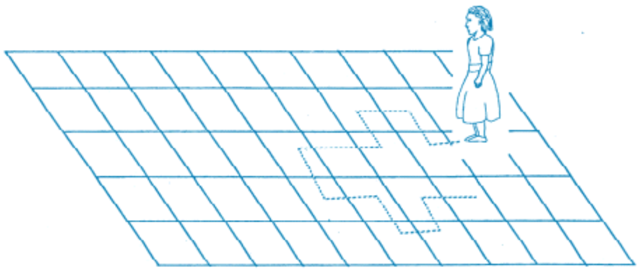
(C) 

(D) 

TAKE A RANDOM WALK

INTRODUCTION :

Things in nature often move in complicated ways. You have probably watched the way a butterfly moves. The molecules of the air that you are breathing move in a similar way. This type of motion we call a random walk. You can also take a random walk.



WHAT YOU NEED:

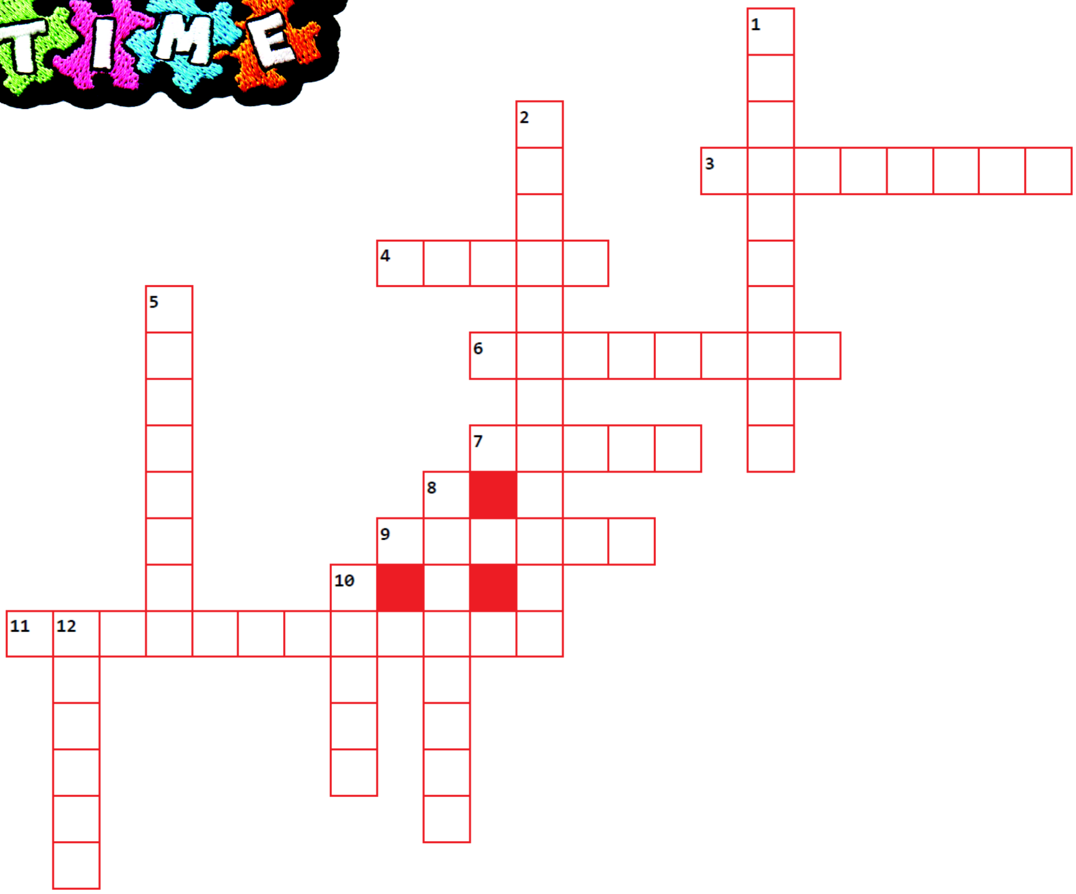
- A coin to flip
- Open space

TRY THIS:

1. Go out to a large open field and mark a spot on the ground. Take with you a coin like a nickel or a quarter. Stand on the spot and flip the coin. If the coin comes up heads, turn to the right and take a large step.
2. If the coin comes up tails, turn to the left and take a large step. Keep doing this many times and see where you end up.

WHAT'S GOING ON?

1. If you flip the coin 25 times you will probably be about five steps away from where you started.
2. This is because five times five equals 25. How far would you expect to be if you flipped the coin 100 times?
3. A random walk is not a very fast way to get anywhere!
4. When you try this, you will notice that sometimes you go much farther than you expect and sometimes you end up very close to where you started.
5. But if you repeat it many times or get several of your friends to do it with you with coins of their own, the average distance should come out as expected. In science we can often predict what will happen on the average even when the process is random.



Across

3. A __________ line represents a constant speed on a distance-time graph.
4. Describes how fast an object is moving.
6. Describes how fast an object is moving and thedirection it is moving.
7. In a distance-time graph, distance is on the_____.
9. All matter in the universe is in constant__________.
11. A change in speed or direction.

Down

1. A _________ line represents no motion on a distance-time graph.
2. When an object slows down.
5. The formula for speed is ________ divided by time.
8. Something is in motion if it is changing__________.
10. In a distance-time graph, time is on the________.
12. A __________ line represents acceleration on adistance-time graph.