MECHANICS AND MOTION

Mechanics a branch of science (physics) is usually divided into two parts which are Kinematics and Dynamics.

Kinetics deals with the mathematical description of the motion of an object without consideration of what causes motion. The branch of science that deals with the study of motion is Kinematics.

Dynamics on the other hand studies the causes of motion. The branch of science that deals with the forces that cause motion is called Dynamics.

Force is responsible for the generation and termination of motion.

A particle is any type of body (object) of negligible size and internal structure.

Forces acting on rigid bodies are divided into two which are external and internal forces. External forces are forces that come from outside for example pull or push. If these external forces are unopposed, each external force could impart a motion of translation, rotation or both.

TYPES OF MOTION

1. Random Motion: This is a motion which describes a zigzag pattern of movement or an irregular pattern of movement. For example the movement of gases or Brownian motion
2. Rotational Motion (Or rotary motion): This is a type of motion that describes a circular pattern of movement e.g. the blades of a rotating ceiling fan
3. Oscillatory motion (or periodic motion): This is a motion that describes a to and fro type of movement e.g. the motion of a simple pendulum bob
4. Translational motion (or linear motion): This is a motion that describes the movement of a whole body from one position to another.

Vibratory

Linear

Rectilinear

Spin Electron motion

A body can experience two or more types of motion at the same time. For example the movement of a car tire can experience translational motion (the motion of the whole body) and rotational motion.

TERMS USED IN MOTION/KINEMATICS

1. Displacement: This is defined as the distance travelled in a specific direction. It can also be described as the distance between the starting point and the end point of a movement
2. Speed: This is defined as the rate at which distance is travelled or the rate of change of distance with time. It is defined mathematically as the distance per unit time. The basic unit of speed (most of the time in physics) is ms-1.

In calculus,

That is you differentiate the distance given with respect to time

Instantaneous speed refers to speed at any instance.

Speed is a scalar quantity and its unit is meters per second and its dimension is

1. Velocity: This is defined as the rate at which displacement is travelled or covered. It is also defined as the rate of change of displacement. It is represented mathematically as displacement per unit time.

In calculus,

Average velocity can be expressed as,

Displacement can also be expressed as,

That is you differentiate the displacement given with respect to time

The terms velocity and speed have distinct definitions in physics and care must be taken not to confuse one for the other.

Instantaneous speed measures how fast a particle is moving at a particular time

Instantaneous velocity measures how fast a particle is moving in a specified direction at a particular time.

Velocity is a vector quantity is a vector quantity and its unit is also meters per second and its dimension is

Acceleration: This is defined as the rate of change of velocity.

Final velocity ------ v

Initial velocity ----- u

In calculus notation,

But,

Therefore,

Acceleration is a vector quantity and its unit is meters per square second. Its dimension is

QUESTIONS

A train changes its position (x) as a function of time (t) expressed as

Here, x is in meters and t is in seconds

Find the instantaneous velocity at time 3s (answer: 30)

Find the displacement of the train between 1second and 2seconds. Also, find the average velocity during that time period. (Answers: 15m and 15ms)

Question 2:

The acceleration which a particle moves is given as

Find its velocity at time 3 seconds given that the velocity at time t=0 is zero meters per second. Ans: 9

Question 3: The displacement (x) of a car as a function of time (t) is given as

Find the velocity of the body at 4 seconds. Ans: 6ms^-1

At what time will the velocity of the body become 0 meters per second? t=1

Question 4: The acceleration of a car is given as a function of time as

If the position (x) and velocity (v) at when time (t) is 0seconds are 0m and 10 ms respectively, what is the velocity of the car after 2 seconds Answer is 13.6

Question 5: The position (S) of a particle moving along the x-axis is given by

Find the acceleration of the particle at two seconds. Ans: 24

Is the velocity constant or changing with time

Since, the velocity is changing with time. The velocity is changing with time since it is a function of time.

EQUATIONS OF UNIFORM ACCELERATION

From the equation of acceleration,

But,

But,

From the difference of two squares,

The above equations are only for constant acceleration. If the body were to be retarding (decelerating), the signs will change from positive to negative

The above equations will change to

It should be noted that the distance covered in the nth second is different from the distance covered in n seconds.

The distance covered in the nth second is the difference between the distance covered in n seconds and the distance covered in (n-1) seconds.

MOTION IN 2D AND 3D

Note the following formulae

Position or displacement,

The change in position,

Average velocity,

Instantaneous velocity,

The magnitude of the instantaneous velocity i.e. the speed is given as,

Instantaneous acceleration vector is,

QUESTIONS

A man runs a distance of 1 kilometre in 5 minutes. His average speed is? Answer:

A car traveling at a uniform speed of spends 15 minutes moving from a point A to point B along its route. The distance between A and B is? Answer: 25km

A train with an initial velocity of is subjected to a uniform deceleration of . The time required to bring the train to complete rest is? Answer: 10s

A body accelerates uniformly from rest at . Its velocity and time after traveling a distance of 24m are? Answer: and

A body accelerates uniformly from rest at for 8 seconds and then decelerates uniformly to rest in the next 5 seconds. Find the magnitude of the deceleration. Answer: 9.6ms^-2

A body undergoing a uniformly-accelerated motion has two points (1s, 10ms^-1) and (20s, 48ms^-1) on the velocity time graph. The acceleration of the body is? Answer: 2ms^-2

A motorist traveling at 72kmh^-1, on siting a stop road sign applies the brakes such that under constant deceleration the car is brought to stop within a distance 50m. The magnitude of the deceleration is

Two bodies X and Y start from rest and move with uniform accelrations of a and 4a respectively. If the bodies cover the same distance in times t\_x and t\_y, then the ration of t\_x to t\_y is? Answer: 2 : 1

A car starting from rest moves with a uniform acceleration of 6ms^-2. The distance it covers in the fourth second of its motion is? Answer: 21m

A fruit drops from the top of a tree 20m tall. The time it takes the fruit to reach the ground is what? What is the velocity just before it hits the ground. Answer: 2s and 20ms^-1

A car decelerates uniformly at from. Calculate the distance traveled by the car. (Answer 105m)

A train travels with an initial velocity of. If it accelerates uniformly atand travels a distance of 100m, calculate the final velocity of the trains. (Answer: 28.3)

Calculate the time taken and the distance covered by a train moving with a velocity ofand then accelerating at the rate ofto reach a velocity of. (Answer: 2.5s and 43.75m)

A car accelerates uniformly on a straight line with an acceleration ofand travels 150m in a time interval of 5s. How far will the car travel in the next 5s? (Answer: 400m)

An automobile and a truck start from rest at the instance with the automobile initially at some distance behind the truck. The truck has a constant acceleration ofand the automobile has an acceleration of. The automobile overtakes the truck has moved 90m.

How long does it the automobile to overtake the truck? (Answer: 7.75)

How far was the automobile behind the truck? (Answer: 30.125)

A man runs a distance of 1km in 5 minutes. What is his average speed (Answer: 3.3ms)

A car travelling at a uniform speed of 100kmh spends 15 minutes moving from point A to point B along its route. The distance between A and B (Answer 25km)

A train with an initial velocity of 20ms is subjected to a uniform deceleration of 2ms. The time required to bring the train to a complete halt is (Answer: 10s)

A body accelerates uniformly from rest at 3ms. Its velocity after traveling a distance of 24m is (Answer: 12ms) and what is the time taken for the body to cover the 24m (Answer: 4s)

A body accelerates uniformly from rest at 6ms for 8s and then decelerates uniformly to rest in the next 5s. What is the magnitude of the deceleration (Answer: 9.6)

A body undergoing a uniform-accelerated motion has two points (1s, 10ms) and (20s, 48ms) on the velocity-time graph of its motion. The acceleration of the body is (Answer 2ms)

A motorist traveling at 72kmh, on siting the stop sign applies the brakes such that under constant deceleration the car is brought to a stop within a distance of 50m. The magnitude of the deceleration is (4ms)

A car starting from rest moves with a uniform acceleration of 6ms. The distance it covers in the fourth second is (Answer: 21m)

The acceleration with which a particle moves is given as . Find its velocity at time t=3, given that the velocity at time t=0 is zero

The displacement s(t) of a car as a function of time tis given as

Find its velocity at time t = 4s. At what time will the velocity of the body become zero?

An elementary particle is projected into space and travelled as

Find its acceleration at t=0

RELATIVE VELOCITY

Bodies moving (acting) in opposite direction: For two bodies A and B moving in opposite direction, the velocity of A relative to B can be obtained by finding the sum of their velocities.

Bodies Moving In the same direction: For two bodies A and B moving in the same direction, the velocity of A relative to B is obtained by finding the difference of their velocities

Bodies moving perpendicular (at 90 degrees) to each other: Their relative velocity can be gotten from Pythagoras’ theorem.

MOTION UNDER GRAVITY

A body falling under the influence of the earth’s gravitational attraction is an example of motion with constant acceleration in a straight line.

All bodies at a particular location fall with the same downward acceleration regardless of their size and weight. This kind of motion is called free fall and the acceleration due to gravity (g) has an approximate magnitude of g = 9.8m/s2

When a body is falling from a given height, it experiences acceleration (due to gravity) and when it is going up it experiences deceleration or retardation (due to gravity). m

All the major linear equations can be converted to linear gravitational motion by some replacements.

(a is acceleration while g is acceleration due to gravity)

Note: When a body is falling it is accelerating (since it acts in the direction of gravity) while when a body is going up it is decelerating (since it acts against gravity)

For falling bodies,

And for rising bodies,

The time required for a body to reach the ground from a given height is given as:

A kangaroo can jump vertically upwards to a height of 2.5m. What is their effective take off velocity? Take g as. (Answer: 7)

A ball thrown vertically upward returns to the thrower two seconds; determine the speed with which it was struck and the maximum height attained by the ball (Answers: 9.8 and 4.1m respectively)

A stone is dropped from the top of a tall building and at the same time another stone is thrown vertically upwards with a velocity of. If the stones meet exactly 25 seconds after their relay, how tall is the building?

A fruit drops from the top of a tree 20m tall. The time it takes for the fruit to reach the ground is (Answer: 2s). What is the velocity of the body before it hits the ground (Answer: 20ms)

A train changes its position (x) as a function of time (t) as follows: x = 20+5.0r^2, with x in metres: Find the displacement of the train between t1 =1s and t2 = s2. Find the instantaneous velocity at time t1 = 3s

Solution

At time , the displacement is

At time , the displacement is 40m. The displacement in that time interval is

The average velocity is

The instantaneous velocity is

At ,

TIME GRAPHS

Distance-Time Graphs: These are graphs which show the relationship between distance and time.

In this graph, the distance is plotted on the vertical axis (y-axis)(ordinates) while the time is plotted on the horizontal axis (x-axis)(abscissas).

The slope of the graph gives the speed of the body.

Displacement-Time Graphs: These are graphs which show the relationship between displacement and time.

In this graph, the displacement is plotted on the vertical axis (y-axis)(ordinates) while the time is plotted on the horizontal axis (x-axis)(abscissas).

The slope of the graph gives the velocity of the body.

Velocity-Time Graph: This graph describes the relationship between velocity and time. In this graph the velocity is plotted against time. The slope of this graph gives the acceleration. The area under the graph (line) gives the total distance covered