Government of Tamilnadu

Department of Employment and Training

Course : TNPSC Group II Exam

Subject : Physics

Topic : **Force, Motion & Energy Work**

FORCE, MOTION & ENERGY WORK

Motion

- Mechanics is one of the oldest branches of physics. It deals with the study of particles or bodies when they are at rest or in motion. Modern research and development in the spacecraft design, its automatic control, engine performance, electrical machines are highly dependent upon the basic principles of mechanics. Mechanics can be divided into statics and dynamics.
- Statics is the study of objects at rest; this requires the idea of forces in equilibrium.
- Dynamics is the study of moving objects. It comes from the Greek word dynamis which means power. Dynamics is further subdivided into kinematics and kinetics.
- Kinematics is the study of the relationship between displacement, velocity, acceleration and time of a given motion, without considering the forces that cause the motion.
- Kinetics deals with the relationship between the motion of bodies and forces acting on them.

Particle

- A particle is ideally just a piece or a quantity of matter, having practically no linear dimensions but only a position.

Rest and Motion

- When a body does not change its position with respect to time, then it is said to be at rest. Motion is the change of position of an object with respect to time. To study the motion of the object, one has to study the change in position (x,y,z coordinates) of the object with respect to the surroundings.
- It may be noted that the position of the object changes even due to the change in one, two or all the three coordinates of the position of the objects with respect to

time. Thus motion can be classified into three types :

(i) Motion in one dimension

Motion of an object is said to be one dimensional, if only one of the three coordinates specifying the position of the object changes with respect to time.

Example : An ant moving in a straight line, running athlete, etc.

(ii) Motion in two dimensions

In this type, the motion is represented by any two of the three coordinates.

Example : A body moving in a plane.

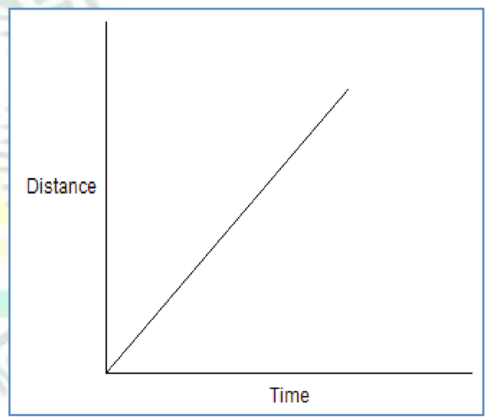
(iii) Motion in three dimensions

Motion of a body is said to be three dimensional, if all the three coordinates of the position of the body change with respect to time.

Examples : Motion of a flying bird, motion of a kite in the sky, motion of a molecule, etc.

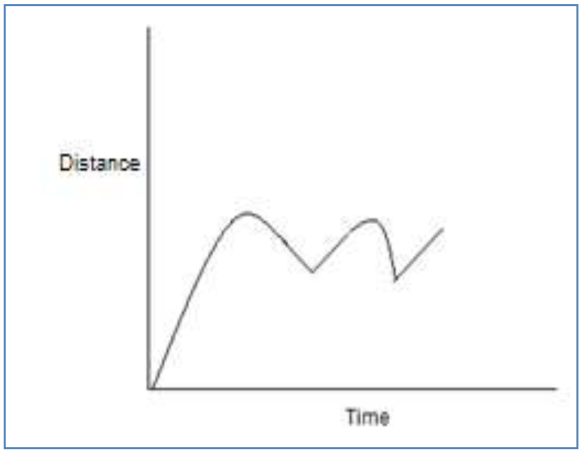
Motion in one dimension (rectilinear motion)

- The motion along a straight line is known as rectilinear motion. The important parameters required to study the motion along a straight line are position, displacement, velocity, and acceleration.
- If an object covers equal distances in equal intervals of time, it is said to be in **uniform motion.**



- If an object covers unequal distance in equal intervals of time, it is said to be in **non-uniform motion.**
- Speed is the quantity used to say whether the motion is slow or fast.

Water in a lake and nearby wells seeks the same level because force of gravity



Displacement

- The shortest distance or distance travelled along a straight line is known as displacement.

Difference between Distance and Displacement

	Distance	Displacement
1.	Distance is the length of the actual path followed by an object or body while moving from one point to another.	Shortest distance between two points
2.	Scalar quantity	Vector quantity
3.	Measured in metre in the SI system	Measured in metre in the SI system
4.	Not a unique quantity	Unique
5.	Distance can either be equal to or greater than displacement	Displacement is either equal to or less than the distance.

Speed

Speed is the distance travelled in one second (or) rate of distance travelled.

$$Speed = \frac{\text{Total Distance Travelled}}{\text{Time Taken}}$$

Speed is measured in m/s (or) ms^{-1}

Velocity

- Velocity is the displacement made in one second (or) rate of change of displacement. Rate of change means change per second.

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

Difference Between Speed and Velocity

	Speed	Velocity
1.	Change of distance with respect to time	Change of displacement with respect to time
2.	Scalar Quantity	Vector Quantity
3.	Measured in m/s in the S.I. System	Measured in m/s in the S.I. System
4.	Positive Quantity	Positive can Negative Quantity

Uniform Velocity

If equal displacements are made by a body in equal intervals of time, then the body has uniform velocity

Acceleration

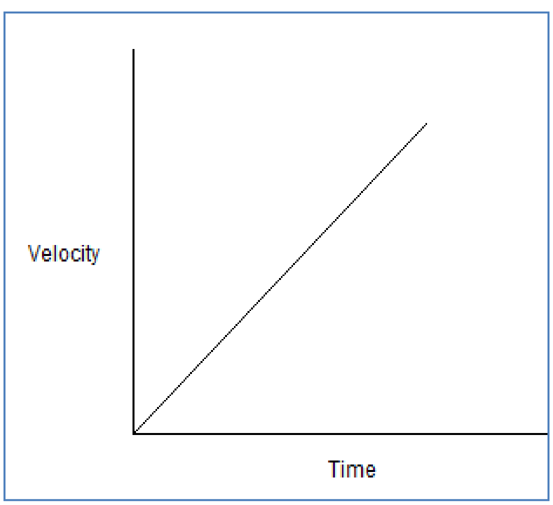
Acceleration is the change in velocity of an object per second or rate of change of velocity.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

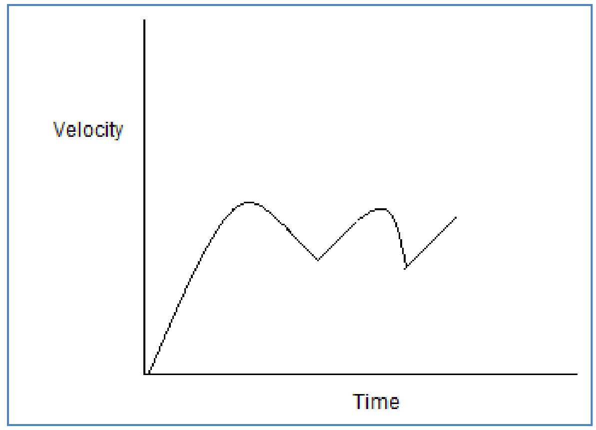
The unit of acceleration is m/s^2 or ms^{-2}

Uniform Acceleration

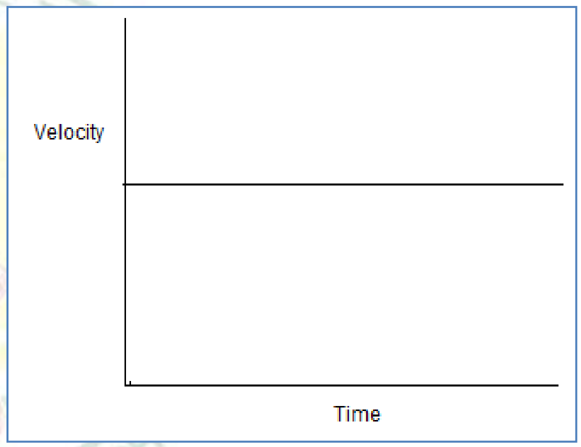
If an object travels in a straight line and its velocity increases or decreases by equal amount in equal intervals of time, then the acceleration of the object is uniform Uniformly accelerated motion.



Non-uniformly accelerated motion



Un - Accelerated Motion



Equation of motion

- $v = u + at$
- $s = ut + \frac{1}{2} at^2$
- $v^2 = u^2 + 2as$
- u - initial velocity
- v = final velocity
- t - time
- a - acceleration
- s - displacement

Body thrown upwards

Equations can be obtained by substituting

$a = -g$ and $s = h$

we get,

$v = u - gt$
$h = ut - \frac{1}{2} gt^2$
$v^2 = u^2 - 2gh$

For the freely falling body

$u = 0$, $a = g$ and $s = h$

Now, the equations will be

$v = gt$
$h = \frac{1}{2} gt^2$
$v^2 = 2gh$

Uniform circular Motion

- An athlete runs along the circumference of a circular path. This type of motion.

Angular displacement

- It is the angle covered by the line joining the body and the centre of the circle (radius vector) when it moves from one point to other in a circular path. It is measured in radian.

Angular velocity

- The angular displacement in one second (rate of change of angular displacement) is called angular velocity.

$$\text{Angular velocity} = \frac{\text{Angular displacement}}{\text{Time taken}}$$

$\omega = \theta$

It is radian / second

Relation between linear velocity and angular velocity
$v = r\omega$

<u>Newton's laws of motion</u>

Newton's first law of motion

It states that everybody continues in its state of rest or of uniform motion along a straight line unless it is compelled by an external force to change that state.

Inertia

Inertia is that property of a body by virtue of which the body is unable to change its state by itself in the absence of external force.

Inertia depends upon its mass of the body.

The inertia is of three types

(i) Inertia of rest

Ex- A person standing in a bus falls backward when the bus suddenly starts moving.

(ii) Inertia of motion

Ex - When a passenger gets down from a moving bus, he falls down in the direction of the motion of the bus.

(iii) Inertia of direction.

Ex - When a bus moving along a straight line takes a turn to the right, the passengers are thrown towards left.

Momentum

- P = MV
- M = Mass
- V = Velocity
- It is Vector Unit
- Unit - kg m/s.

Newton's second law of motion

- ❖ The rate of change of momentum of a body is directly proportional to the external force applied on it and the change in momentum takes place in the direction of the force.

  F=ma

- ❖ The unit of force is kg m s^{-2} or Newton. Its dimensional formula is MLT^{-2}.

Example : 1

A constant force acts on an object of mass 10 kg for a duration of 4 s. It increases the objects velocity from 2 ms^{-1} to 8 m s^{-1} Find the magnitude of the applied force.

Solution:

Given, mass of the object m = 10 kg

Initial velocity u = 2 m s^{-1}

Final velocity v = 8 m s^{-1}

We know, force

$$F = \frac{m(v-u)}{t}$$

$$F = \frac{10(8-2)}{4} = 15\ N$$

Example : 2

Which would require a greater force for accelerating a 2 kg of mass at 4 m s^{-2} or a 3 kg mass at 2 m s^{-2}?

Solution

We know, force F = ma

Given m1 = 2kg a_1 = 4 ms^{-2}

m_2 = 3 kg a_2 = 2m s^{-2}

Thus, $F_1 = m_1 a_1$ = 2kg × 4m s^{-2} = **8 N**

and $F_2 = m_2 a_2$ = 3kg × 2m s^{-2} = **6 N**

⇒ F1 > F2

Impulsive force and Impulse of a force

(i) Impulsive Force

An impulsive force is a very great

A jet engine works under the principle of Law of conservation of Newton's third law linear momentum.

force acting for a very short time on a body, so that the change in the position of the body during the time the force acts on it may be neglected.

(e.g.) The blow of a hammer, the collision of two billiard balls etc.

(ii) Impulse of a force

The impulse J of a constant force F acting for a time t is defined as the product of the force and time.

(i.e) Impulse		= Force × time
	J	= F × t

Impulse of a force is a vector quantity and its unit is Ns.

Newton's third Law of motion

For every action, there is an equal and opposite reaction.

Applications of Newton's third law of motion

(i) Apparent loss of weight in a lift

(ii) Working of a rocket and jet plane force

Centripetal Force

The constant force that acts on the body along the radius towards the centre and perpendicular to the velocity of the body is known as centripetal force

$$F = \frac{mv^2}{r} \qquad \therefore (\text{since } v = r\omega)$$

$$F = mr\omega^2$$

Examples

1. In the case of the stone tied to the end of a string and rotated in a circular path, the centripetal force is provided by the tension in the string.
2. When a car takes a turn on the road, the frictional force between the tyres and the road provides the centripetal force.
3. In the case of planets revolving round the sun or the moon revolving around the earth, the centripetal force is provided by the gravitational force of attraction between them
4. For an electron revolving around the nucleus in a circular path, the electro static force of attraction between the electron and the nucleus provides the necessary centripetal force.

When a body moves with uniform velocity its acceleration is zero

Centrifugal force

- The force which is equal in magnitude but opposite in direction to the centripetal force is known as centrifugal force.

Example : While churning curd, butter goes to the side due to centrifugal force.

Friction : Whenever a body slides over another body, a force comes into play between the two surfaces in contact and this force is known as frictional force. The frictional force always acts in the opposite direction to that of the motion of the body. The frictional force depends on the normal reaction. (Normal reaction is a perpendicular reactional force that acts on the body at the point of contact due to its own weight) (i.e) Frictional force α normal reaction $F \alpha R$ (or) $F = \mu R$ where μ is a proportionality constant and is known as the coefficient of friction. The coefficient of friction depends on the nature of the surface

Gravitation

- Newton concluded that all objects in the universe attract each other. This force of attraction between objects is called the gravitational force

Mass

- Mass is the amount of matter present in a body (or) is a measure of how much matter an object has.

Weight

Weight is the force which a given mass feels due to the gravity at its place (or) is a measure of how strongly gravity pulls on that matter.

	Mass	Weights
1.	Fundamental Quantity	Derived Quantity
2.	It is the amount of matter contained in a body	It is the gravitational pull acting on the body
3.	It's unit is kg	It is measured in newton
4.	Remains the same	Varies from place to place
5.	It is measured using physical balance	It is measured using spring balance

The energy gap of diamond is 7ev

Example : 1

Mass of an object is 5 kg. What is its weight on the earth?

Solution:

Mass, m = 5 kg Acceleration due to gravity, g = 9.8 m s^{-2}

Weight, w = m × g

w = 5 kg × 9.8 m s^{-2} = 49 N

Thus the weight of the object is, **49 N**

Example : 2

Calculate the energy produced when 1 kg of substance is fully converted into energy.

Solution: Energy produced, $E = mc^2$

Mass, m = 1 kg Velocity of light, c = 3×108 m s-1 E = 1 × (3 × 108)²

$E = 9 \times 10^{16}$ J

> **"In the absence of air, all bodies will fall at the same rate".**

Acceleration due to gravity

The gravitational force experienced by the body is $F = \frac{GMm}{R^2}$ where M is the R² mass of the earth. From Newton's second law of motion,

Force, F = mg

Equating the above two forces,

$$F = \frac{GMm}{R^2} \qquad (\therefore\ F = mg)$$

$$mg = \frac{GM}{R^2}$$

Therefore,

$$g = \frac{GM}{R^2}$$

Mass of earth

From the expression $g = \frac{GM}{R^2}$, the mass of the Earth can be calculated as follows:

$$M = \frac{gR^2}{M}$$

$$M = \frac{9.8 \text{ x } (6.38 \text{ x } 10^6)^2}{6.67 \text{ x } 10^{-11}}$$

$$M = 5.98 \times 10^{24} \text{ kg.}$$

Energy

- Energy can be defined as the capacity to do work. Energy can manifest itself in many forms like mechanical energy, thermal energy, electric energy, chemical energy, light energy, nuclear energy, etc. The energy possessed by a body due to its position or due to its motion is called mechanical energy. The mechanical energy of a body consists of potential energy and kinetic energy.

The path of a projective is parabola.

Potential energy

- The potential energy of a body is the energy stored in the body by virtue of its position or the state of strain. $E_P = mgh$

Example : Water stored in a reservoir, a wound spring, compressed air, stretched rubber chord, etc,

Kinetic energy

- The kinetic energy of a body is the energy possessed by the body by virtue of its motion.
  Kinetic energy $E_k = \frac{1}{2} Mv^2$
- A falling body, a bullet fired from a rifle, a swinging pendulum, etc.

Power

- It is defined as the rate at which work is done.

$$\boxed{\text{Power} = \frac{\text{Work Done}}{\text{Time}}}$$

- Its unit is watt and dimensional formula is $ML^2\,T^{-3}$.