According to new syllabus of all intermediate boards of Sindh.

Prof. Rawala's ....

PHYSICS

HELPING BOOK

For
Class XI
(All science students)

UNIT -3

Dynamics.

Notes .... (03)
Multiple choice questions **M.C.Qs.** ....(11)
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- **Newton's laws of motion, momentum, impulse, law of conservation of momentum.**
- **Elastic and inelastic collisions. Elastic collision in one dimension.**
- **Friction, cause of friction, types of friction.**
- **Coefficient of friction.**
- **Angle of friction, angle of repose.**

Thoroughly revised and updated 2026 – 2027

- ***Detailed notes.***
- ***Multiple Choice Questions (M.C.Q's).***
- ***Solution of text book numericals.***
- ***MCQs and solution of numericals from Karachi board past papers.***

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Unit. 3..... ✍

Dynamics.

Dynamics is the branch of mechanics that deals with motion of a body with reference to force.

Newton's laws of motion:

First law of motion:

According to Newton's first law of motion:

"A body tends to continue its state of rest or of uniform motion unless a force is applied on it".

Hence in the absence of any external force a body at rest will remain at rest and a body in motion will continue its motion along a straight line with uniform speed.

In reality we see that a body in motion comes to rest after covering some distance. This is so because frictional forces, such as air resistance, contact friction etc. bring the body to rest. If all these frictional forces are eliminated, however they may be small, then the body will continue its motion with uniform velocity.

- First law of motion is also known as ***law of inertia***.

Inertia:

Inertia is the property of matter by virtue of which it tends to oppose any change in its state of rest or of uniform motion.

Hence if a body is at rest it will tend to remain at rest forever unless a force is applied to move it, similarly if a body is in motion it will tend to continue its motion with uniform velocity unless a force is applied to change its velocity.

Inertia of a body depends upon its mass greater the mass of a body larger is its inertia and therefore, more difficult it is to stop it if it in motion or to move it if it is at rest. Hence ***mass of a body is a measure of its inertia***.

Second law of motion:

According to second law of motion:

"When an unbalanced force acts on a body it produces acceleration in the body in its own direction such that the magnitude of acceleration is directly proportional to the magnitude of force and inversely proportional to mass of the body".

If '$\vec{F}$' is the unbalanced force, acceleration produced is '$\vec{a}$' and 'm' is mass of the body, then: $\vec{a} \propto \vec{F}$ and $\vec{a} \propto 1/m$ $\therefore$ $\vec{a} \propto \frac{\vec{F}}{m}$ $a = k\frac{F}{m}$ (But k=1)

$$\therefore \quad \boxed{\vec{F} = m\vec{a}}$$

Direction of acceleration '$\vec{a}$' produced in the body is always ***same*** as the direction of unbalanced force $\vec{F}$ (unbalanced force is the resultant or vector sum of all the forces acting on the body).

***Unit of force*:** Unit of force can be defined with the help of second law of motion, according to which: $F = m\,a$

Hence the S.I unit of force will be 'kg-m/s^2' which is commonly known as ***Newton***.

" Force is said to be one Newton (1N) if it produces an acceleration of 1 m/s^2 in a body of mass 1 kg".

***Q No.1*: Can a balanced force produce acceleration in a body?**

***Ans*:** Acceleration is produced only by **unbalanced force** (when a balanced force acts on a body the body either remains at rest or moves with a uniform velocity.

Third law of motion:

According to Newton's third law of motion:

"To every action there is an equal and opposite reaction".

Action and reaction are two forces exchanged between two bodies when the interact with each other.

***Q.No.3*: Do action reaction cancel each other since they are equal and opposite forces?**

Ans*:** Two equal and opposite forces acting on the ***same body cancel each other. Although action and reaction are equal and opposite forces but they act ***on two different bodies***. Action is the force exerted by first body on the second whereas reaction is an equal and opposite force applied by the second on first. Hence they ***do not*** cancel each other.

Momentum:

***Q No.1*: What is momentum?**

***Ans*:** Momentum may be defined as:

'The product of mass and velocity of a body'.

Hence: Momentum = mass × velocity

$$\text{Momentum} = m\,\vec{v}$$

Momentum of a body depends upon its ***mass*** and ***velocity***.

Momentum of a moving body actually represents the quantity of motion present in the body.

- ❖ Momentum tells us how difficult or how easy it is to stop a moving body. It is difficult to stop a body having large momentum. (***In other words,*** it is difficult to stop a ***fast moving*** and a ***heavy*** body).
- ❖ Momentum is a ***vector quantity***; its direction is ***same*** as the direction velocity of the body.

S.I unit and dimensions of momentum:

The ***unit of momentum*** is the product of units of mass and velocity.

Hence the S.I unit of momentum is kg-m/s which is same as ***N-s***.

Dimensions of momentum are [MLT^{-1}].

***Q.No.2*: What is the relation between momentum and second law of motion?**

***Ans*:** When a force acts on a body it changes its momentum such that the rate of change in momentum of the body is equal to the force acting on it. This is the relation between momentum and second law of motion.

***Q.No.3*: Derive a relation between momentum of a body and second law of motion.**

***Ans*:** Consider a body of mass 'm' moving with a certain velocity 'v_i'. Let a force 'F' be applied on it for time 'Δt' such that velocity of the body changes and becomes 'v_f'.

Therefore: Initial momentum = $m\,v_i$

Final momentum = $m\,v_f$

Change in momentum = $m\,v_f - m\,v_i$

$\therefore$ Rate of change in momentum $= \dfrac{m v_f - m v_i}{\Delta t} = \dfrac{m (v_f - v_i)}{\Delta t}$

But $\dfrac{v_f - v_i}{\Delta t} = a$ (Acceleration of the body)

Hence, Rate of change of momentum of a body = m a

But m a = F (Force)

$\therefore$ Rate of change of momentum of a body = Force acting on the body

$$F = \frac{m v_f - m v_i}{\Delta t}$$

In vector form: $\vec{F} = \dfrac{m \vec{v}_f - m \vec{v}_i}{\Delta t} = \dfrac{\Delta \vec{p}}{\Delta t} = \dfrac{\text{change in momentum}}{\text{Time}}$

"When a net (or unbalanced) force acts on a body it changes its momentum such that the rate of change of momentum of the body is equal to the force".

Impulse:

Q No.4: What is impulse of force?

Ans: Impulse "$\Delta \vec{p}$" of a force is the product of force '$\vec{F}$' and the short interval of time 'Δt" for which it acts.

- Impulse is a ***vector quantity***.
- It is also equal to the change in momentum of the body. Hence

$$\boxed{\vec{F}\,\Delta t = \Delta \vec{p}}$$

Law of conservation of linear momentum:

Q.No.1: State law of conservation of linear momentum?

Ans: According to law of conservation of momentum:

"If no external force acts on a system of two or more interacting bodies the total linear momentum of the system remains constant."

It means that when bodies interact (collide with each other, exerting action-reaction forces upon each other) in a system on which no external force is acting, momentum of individual bodies may change. Some bodies may gain and some may loose, but the total momentum of the system before collision is equal to the total momentum after collision.

Proof of law of conservation of momentum:

Q.No.2 Prove law of conservation of momentum?

Ans: Consider a system of two colliding bodies of masses 'm_1' and 'm_2' moving with velocities 'U_1' and 'U_2' respectively in the same direction, such that no external force acts on them. 'm_2' is behind 'm_1' and is moving faster than m_1. There will be a collision between the two bodies. Let their velocities after collision be 'V_1' and 'V_2' respectively.

Therefore, when the bodies come in contact with each other only action and reaction forces are exchanged between them.

Let 'Δt' be the time for which the bodies come in contact with each other during the collision, and 'F_{12}' be the force acting on 'm_1' (exerted by m_2), then:

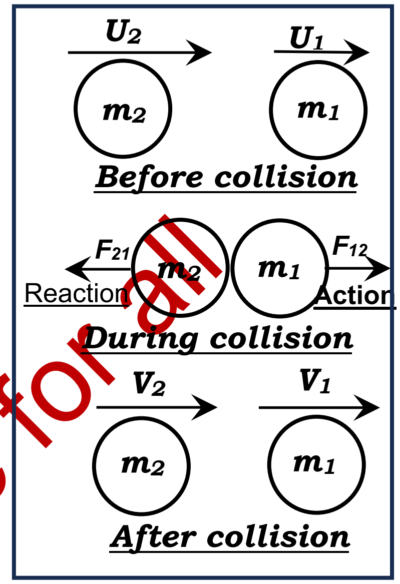
$$F_{12} = \frac{m_1 V_1 - m_1 U_1}{\Delta t} \qquad \text{(Action force)}$$

Similarly force 'F_{21}' acting on m_2 (exerted by m_1) is given by:

$$F_{21} = \frac{m_2 V_2 - m_2 U_2}{\Delta t} \text{ (reaction force)}$$

Their velocities after collision be 'V_1' and 'V_2' respectively.

Since the system is isolated (***It means that*** no external force acts on the two bodies), therefore, when the bodies come in contact with each other only action and reaction forces are exchanged between them.



Let 'Δt' be the time for which the bodies come in contact with each other during the collision, and 'F_1' be the force acting on 'm_1' (exerted by m_2), then:

$$F_{12} = \frac{m_1 V_1 - m_1 U_1}{\Delta t} \qquad \text{(action force)}$$

Similarly force 'F_2' acting on m_2 (exerted by m_1) is given by:

$$F_{21} = \frac{m_2 V_2 - m_2 U_2}{\Delta t} \qquad \text{(reaction force)}$$

According to third law of motion, action and reaction are equal and opposite, hence

$$\vec{F}_{12} = -\vec{F}_{21} \quad \text{OR} \quad \frac{m_1 V_1 - m_1 U_1}{\cancel{\Delta t}} = -\frac{(m_2 V_2 - m_2 U_2)}{\cancel{\Delta t}}$$

$$m_1 V_1 - m_1 U_1 = -m_2 V_2 + m_2 U_2$$

$$m_1 U_1 + m_2 U_2 = m_1 V_1 + m_2 V_2$$

Left hand side of the above equation gives us the ***total momentum of the colliding bodies before*** and right-hand side gives us their ***total momentum after collision***.

$\therefore$ ***Total momentum before collision = Total momentum after collision***

In other words, If no external force acts on a system of colliding bodies the total momentum always remains constant (Or Momentum of a system is said to be ***conserved***). Momentum of individual bodies may change, body/bodies may gain and body/bodies may loose but if no external force acts on a system then total momentum of the system remains constant.

Elastic collisions:

Q.No.3: What are elastic collisions?

Ans: Elastic collisions are those in which ***momentum*** as well as ***kinetic energy*** of the system is conserved. ***It means that*** during an elastic collision:

- Total momentum before collision = Total momentum after collision.
- Total kinetic energy before collision= Total kinetic energy after collision.

(Elastic collision takes place between ***hard*** bodies having ***smooth*** surface)

Inelastic collisions:

Q.No.4: What are inelastic collisions?

Ans: Inelastic collisions are those in which momentum of the colliding bodies ***may be conserved*** but kinetic energy is ***not*** conserved. ***In other words***:

- Total momentum before collision may be equal to total momentum after collision.
- Total K.E before collision ***is not equal*** to total K.E after collision.

🗣During an Inelastic collisions kinetic energy of the system is converted into ***other forms of energy*** (mostly into heat energy).

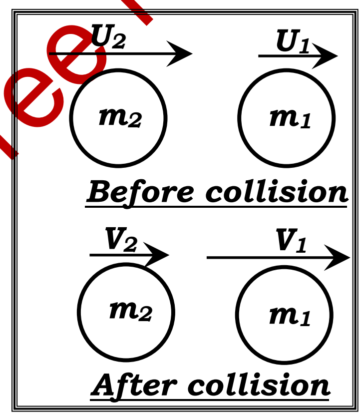
- Inelastic collision takes place between ***soft*** and ***rough*** bodies; the kinetic energy is converted partly into heat and partly used to change shape of the colliding bodies.
- When two cars collide, they dent each other (***in other words*** they change each other's shape). For making a dent on the other car each car has to do work on the other using its own kinetic energy. Also, bodies of colliding cars get slightly hot.

***Q.No.5*: What is one dimensional collision?**

***Ans*:** One dimensional collision is that in which the colliding bodies move along the same line before and after the collision.

Elastic collision in one dimension:

***Q.No.6*: Two spherical non-rotating bodies of masses 'm_1' and 'm_2' moving with velocities 'U_1' and 'U_2' respectively collide elastically. Assuming that both the bodies move along the same straight line before and after the collision, that passes through their centers, derive expressions for their final velocities 'V_1' and 'V_2'.**



***Ans*:** Consider two solid spherical non-rotating bodies of masses 'm_1' and 'm_2' moving with velocities 'U_1' and 'U_2' respectively along the same line which passes through their centers. Let the body of mass "m_2" be behind "m_1" and $U_2>U_1$, then there will be a collision between the two bodies (this collision is one dimensional, because the two bodies move along the same straight line which passes through their centers before and after the collision). Let "V_1"and "V_2" be their velocities after collision.

Assuming the collision to be elastic (for which momentum and kinetic energy both must be conserved), on applying law of conservation of momentum we get:

Total momentum before collision = Total momentum after collision

$$m_1U_1 + m_2U_2 = m_1V_1 + m_2V_2$$

$$m_1U_1 - m_1V_1 = m_2V_2 - m_2U_2$$

$$m_1(U_1 - V_1) = m_2(V_2 - U_2) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (i)$$

Similarly on applying law of conservation of kinetic energy we get:

Total initial kinetic energy = Total final kinetic energy

$$\tfrac{1}{2}m_1U_1^2 + \tfrac{1}{2}m_2U_2^2 = \tfrac{1}{2}m_1V_1^2 + \tfrac{1}{2}m_2V_2^2$$

$$\tfrac{1}{2}m_1U_1^2 - \tfrac{1}{2}m_1V_1^2 = \tfrac{1}{2}m_2V_2^2 - \tfrac{1}{2}m_2U_2^2$$

$$\tfrac{1}{2}m_1(U_1^2 - V_1^2) = \tfrac{1}{2}m_2(V_2^2 - U_2^2)$$

$$m_1(U_1 - V_1)(U_1 + V_1) = m_2(V_2 - U_2)(V_2 + U_2) \quad \ldots\ldots\ldots\ (ii)$$

***Derivation of "V_1"*:**

Divide equation (*ii*) by the corresponding sides of equation (*i*).

$$\frac{m_1(U_1 - V_1)(U_1 + V_1)}{m_1(U_1 - V_1)} = \frac{m_2(V_2 - U_2)(V_2 + U_2)}{m_2(V_2 - U_2)}$$

$$U_1 + V_1 = V_2 + U_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (iii)$$

$$\therefore \quad V_2 = U_1 + V_1 - U_2$$

Substituting the above value of "V_2" in equation (*i*), we get:

$$m_1(U_1 - V_1) = m_2(U_1 + V_1 - U_2 - U_2)$$

$$m_1U_1 - m_1V_1 = m_2U_1 + m_2V_1 - 2m_2U_2$$

$$m_1V_1 + m_2V_1 = m_1U_1 - m_2U_1 + 2m_2U_2$$

$$V_1(m_1 + m_2) = (m_1 - m_2)U_1 + 2m_2U_2$$

$$\therefore \qquad \boxed{V_1 = \frac{(m_1 - m_2)}{(m_1 + m_2)} U_1 + \frac{2m_2}{(m_1 + m_2)} U_2}$$

Derivation of "V_2":

From equation (*iii*) we have: $V_2 = U_1 + V_1 - U_2$

On substituting the value of "V_1", we get:

$$V_2 = U_1 + \frac{(m_1 - m_2)}{(m_1 + m_2)} U_1 + \frac{2\,m_2 U_2}{(m_1 + m_2)} - U_2$$

$$V_2 = U_1 \left\{ 1 + \frac{(m_1 - m_2)}{(m_1 + m_2)} \right\} + U_2 \left\{ \frac{2\,m_2}{(m_1 + m_2)} - 1 \right\}$$

$$V_2 = U_1 \left\{ \frac{(m_1 + m_2) + (m_1 - m_2)}{(m_1 + m_2)} \right\} + U_2 \left\{ \frac{2\,m_2 - (m_1 + m_2)}{(m_1 + m_2)} \right\}$$

$$\boxed{V_2 = \frac{2\,m_1}{(m_1 + m_2)} U_1 + \frac{(m_2 - m_1)}{(m_1 + m_2)} U_2}$$

Friction:

Q No.1: What is friction?

Ans: Friction is a force which opposes motion of a body.

Force of friction exists between a body and the surface on which the body lides/rolls or between the body and the viscous medium through which it moves.

Hence force of friction is always against the direction of motion of a body and it acts parallel to the surfaces in contact.

Origin of friction (Cause of friction).

Classical physics:

According to classical physics when two surfaces are in contact, their irregular surfaces are inter-locked. Hence to move one surface over the other an extra force called ***force of friction*** is needed.

Modern physics:

According to modern physics, when two surfaces are in contact, intermolecular force of attraction between molecules of the two surfaces resist the motion of one surface over the other thus causing ***force of friction***.

Types of friction:

- Friction between the body and the surface when the body is at ***rest*** relative to the surface and tends to move is called ***static friction***.
- Force of friction between a body and a surface relative to which it is in motion is called ***kinetic or dynamic friction***. Kinetic friction is slightly ***less*** than the static friction.
- When a body slides on a surface the corresponding force of friction between the body and the surface on which it slides is called ***sliding friction***.
- When a body rolls on a surface the corresponding force of friction between the body and the surface on which it rolls is called ***rolling friction***.

🗣Force of friction depends upon ***roughness*** of surfaces in contact, their ***temperature***, their ***material***, their ***area of contact*** etc. Hence rolling friction is less than the sliding friction because area of contact between surface and the rolling body will be less.

🗣Force of friction is a ***self-adjusting force.*** Hence when a gradually increasing force is applied on a body at rest it is balanced by the force of friction because of its self-adjusting nature and the body still remains at rest, until a certain limit is reached. If the applied force is increased beyond this limit the body starts moving with acceleration (in accordance with second law of motion). The maximum force of friction between the body and the surface up to which it remains at rest is called ***limiting friction***.

Force of friction "f" is directly proportional to the normal reaction "R" or the force with which the body presses the surface. $f \propto R$

$$\boxed{f = \mu R}$$

Where "μ" is the constant of proportionality it is known as ***coefficient of friction***. Coefficient of friction is of two types:

(*i*) Coefficient of static friction μ_s.

(*ii*) Coefficient of kinetic friction μ_k.

$\mu_k < \mu_s$ because force of friction between the body and the surface when the body is in motion is less than when it is at rest.

- ❖ Force of friction can be decreased by either making the surfaces smooth, by using a lubricant, by using ball bearings or by making a fast-moving body oblong in shape.

<u>Q.No.2</u>: Why is force of friction called a self-adjusting force?

<u>Ans</u>*:** When the force applied on a stationary body is increased from a very low value, force of friction also increases so that the body still remains at rest, until a maximum value of force of friction (called limiting friction) is reached. If the applied force is increased beyond the limiting friction the body starts moving with acceleration. In other words, before moving, force of friction adjusts its value equal and opposite to the applied force so that the body remains at rest, hence, it is called ***<u>self-adjusting force</u>.

<u>Q.No.3</u>: What is coefficient of friction?

***<u>Ans</u>*:** Coefficient of friction is the ratio of force of friction "f" to the normal reaction "R".
Coefficient of friction is of two types:

(i) Coefficient of static friction μ_s. (At rest)

(ii) Coefficient of kinetic friction μ_k. (In motion)

$$\boxed{\mu_s > \mu_k}$$

<u>Q.No.4</u>: What is the S.I unit of coefficient of friction?

***<u>Ans</u>*:** Since coefficient of friction is a ratio of two similar quantities, hence, it <u>does not have any unit</u>.

<u>Angle of friction</u>:

<u>Q.No.5</u>: What is angle of friction?

***<u>Ans</u>*:** Angle of friction is the angle between force of friction "f" and the normal reaction "R".
If "α" is the angle of friction, then $\tan \alpha = \mu$

Where "μ" is the coefficient of friction. It means that tangent of angle of friction is also called **<u>coefficient of friction</u>**.

<u>Angle of repose</u>:

<u>Q.No.6</u>: What is angle of repose?

<u>Ans</u>*:** Angle of repose is the ***<u>minimum angle</u> made by an inclined surface with the horizontal at which a body placed on the inclined surface just starts sliding.

Relation between angle of repose "θ" and angle of friction "α":

Q.No.7: What is the relation between angle of repose and angle of friction?

***Ans*:** Relation between angle of repose θ and the corresponding angle of friction α is that

$$\theta = \alpha$$

<u>Section–A Multiple-Choice Questions MCQs</u>:

Q.No.1: The rate of change of linear momentum of a body is called:
(A) Linear force. (B) Angular force.
(C) Power. (D) Impulse.

Q.No.2: The term mass refers to the same physical concept as:
(A) Weight. (B) Inertia.
(C) Force. (D) Acceleration

Q.No.3: Which one of the following force is also called as self-adjusting force?
(A) Frictional force. (B) Tension.
(C) Weight. (D) Thrust.

Q.No.4: The laws of motion show the relationship between:
(A) Velocity and acceleration.
(B) Mass and velocity.
(C) Mass and acceleration.
(D) Force and acceleration

Q.No.5:: The motion of a rocket in space is according to the law of conservation of:
(A) Energy. (B) Linear momentum.
(C) mass. (D) Angular momentum.

Q.No.6: A bomb of mass 12 kg. initially at rest explodes into two pieces of masses 4 kg and 8 kg. The speed of 8 kg. mass is 6 m/s. The kinetic energy of 4 kg. mass is:
(A) 32 J (B) 48 J (C) 114 J (D) 288 J

Q.No.7: If momentum is increased by 20% then K.E increases by:
(A) 44% (B) 55% (C) 66% (D) 77%

Q.No.8: The kinetic energy of mass 2 kg. and momentum of 2 Ns is:
(A) 1 J (B) 2 J (C) 3 J (D) 4 J

Q.No.9: For the same kinetic energy, the momentum is maximum for:
(A) an electron. (B) a proton.
(C) a deuteron. (D) alpha particle.

Q.No.10: A 3 kg. bowling ball experiences a net force of 15 N. What will be its acceleration.
(A) 35 m/s^2. (B) 7 m/s^2 (C)5 m/s^2 (D)35 m/s^2

Q.No.11: The unit of linear momentum is:
(***2003, 2004 Karachi Board***)
(A) N/s (B) Ns (C) Js (D) J/s

Q.No.12:The rate of change of linear momentum is equal to:
(***2004 Karachi Board***)
(A) Acceleration. (B) force. (C) torque

Q.No.13: In an elastic collision of two bodies: (***2008 Karachi Board***)
(A) Kinetic energy is conserved.
(B) Momentum is conserved.
(C) Both K.E and momentum are conserved.

Q.No.14:The property of fluids due to which they resist their flow is called:
(***2012 Karachi Board***)
(A) Static friction. (B) Coefficient of friction.
(C) Viscosity. (D) Terminal velocity.

Q.No.15: A helicopter weighing 3920 N is moving up with a constant speed of 4 m/s. The force on the helicopter is:
(***2012 Karachi Board***)
(A) 4720 N (B)3920N (C)3924N (D)3916 N

Q.No.16: Kinetic friction is always:
(***2016 Karachi Board***)
(A) Greater than static friction.
(B) Equal to static fiction.
(C) Less than static fiction. (D) Zero.

Q.No.17: If 'F' be the limiting friction and 'R' be the normal reaction, then the coefficient of static friction will be equal to:
(***2019, 2015 Karachi Board***)
(A) F / R (B) R / F (C) F R (D) 1 / F R

Q.No.18: If the average velocity of a body is equal to instantaneous velocity, the body is said to be moving with:
(***2025 Karachi Board***)
(A) Uniform velocity. (B) Variable velocity
(C)Uniform acceleration (D)Variable acceleration

Q.No.19: This force is called "Self-adjusting force". (***2025 Karachi Board***)
(A) Tension. (B) Frictional force
(C) Weight. (D) Thrust

Q.No.20: Change in momentum is equal to:
(***2026 Karachi Board***)
(A) Force. (B) Power.
(C) Impulse. (D) Kinetic energy.

***Answers*:**

(1) (A) Linear force.
(2) (B) Inertia.
(3) (A) Frictional force.
(4) (D) Force and acceleration
(5) (B) Linear momentum.
(6) (D) 288 J
(7) (A) 44%
(8) (A) 1 J
(9) (D) alpha particle.
(10) (C) 5 m/s^2.
(11) (B) Ns
(12) (B) force.
(13) (C) Both K.E and momentum are conserved.
(14) (C) Viscosity.
(15) (B) 3920 N.
(16) (C) Less than static fiction.
(17) (A) F / R
(18) (A) Uniform velocity.
(19) (B) Frictional force.
(20) (C) Impulse.

Numericals:

***Q.No.1*: A car weighing 9800 N is moving with a speed of 40 km./h. on the application of the brakes it comes to rest after traveling a distance of 50 m. Calculate the average retarding force.**

***Data*:**

Weight of the car W = 9800 N.

Initial velocity $v_i = 40 \text{ km/h.} = \frac{40\times1000}{60\times60}\frac{\text{m}}{\text{s}} = 11.11\text{m/s}$

Final velocity $v_f = 0$

Distance covered S = 50 m.

Average force F =?

***Solution*:**

$$2aS = v_f^2 - v_i^2$$
$$2 \times a \times 50 = (0)^2 - (11.11)^2$$
$$100\, a = -123.457$$
$$a = -\frac{123.457}{100} = \boldsymbol{-1.23457\ m/s^2}$$

If 'm' is mass of the car, then: W = m g

$$\therefore \quad m = \frac{W}{g} = \frac{9800}{9.8} = \textbf{1000 kg.}$$

F = m a (second law)

$$\therefore \quad F = 1000\times -1.23457 \qquad \boxed{F = -1234.57N}$$

Negative sign shows that the retarding force acting on the car is ***1234.57N***.

***Q.No.2*: A helicopter weighs 3920 newton. Calculate the force on it if it is ascending at the rate of 2 m/s². What will be the force on it if it is moving up with a constant speed of 4 m/s?**

***Data*:**

Weight W = 3920 N.

Upward acceleration $a = 2\ m/s^2$.

Constant speed v = 4 m/s.

Force on the helicopter F =?

***Solution*:**

In the first case helicopter is moving upward with an acceleration of 2 m/s², therefore, the upward lifting force "F" exerted by its engine and blades is greater than its weight "W" (downward).

Hence,

Unbalanced force = F – W

F – W = ma (by second law)

$$\text{But} \quad m = \frac{W}{g} = \frac{3920}{9.8} = \textbf{400 kg.}$$

$$\therefore \quad F - 3920 = 400\times2$$
$$F - 3920 = 800$$
$$F = 3920 + 800 \qquad \boxed{F = 4720\ N}$$

In the second case, the helicopter moves up with a constant speed, therefore, it's acceleration 'a' will be zero

$$\therefore \quad F - W = ma \qquad F - W = 0$$
$$\therefore \quad F = W \qquad \boxed{F = 3920\ N.}$$

***Q.No.3*: A 100 gm. bullet is fired from a 10 kg. gun with a speed of 1000 m/s. What is speed of recoil of the gun?**

***Data*:**

Mass of bullet m =100 gms = 0.1kg

Mass of the gun M = 10 kg.

Speed of the bullet V_1=1000 m/s.

Speed of the gun V_2 =?.

***Solution*:**

According to law of conservation of momentum:

Total initial momentum = Total final momentum

Since the gun and the bullet both are initially at rest, therefore, total initial momentum is zero. Applying law of conservation of momentum we get:

$$0 = m V_1 + M V_2$$
$$0 = 0.1 \times 1000 + 10 V_2$$
$$10 V_2 = -100$$
$$\therefore \quad V_2 = -\frac{100}{10} \qquad \boxed{V_2 = -10\ m/s.}$$

Negative sign shows that after firing the bullet, the gun moves backward (opposite to the direction of motion of the bullet). This backward movement of the gun after firing is called recoil of the gun.

***Q.No.4*: A machine gun fires 10 bullets per second into a target. Each bullet weighs 20 gm. and had a speed of 1500 m/s. Find the force necessary to hold the gun in position.**

***Data*:**

Mass of each bullet m =20 gm =0.020 kg

Number of bullets fired per sec. = 10

Velocity of each bullet after firing V=1500 m/s

Force necessary to hold the gun in position F=?

***Solution*:**

Machine gun and the bullets form one system. Before firing both are at rest, their total initial momentum is zero. To conserve momentum their total momentum after firing must also be zero. This is possible only if the machine gun has equal and opposite momentum (after firing) to that of the bullet. ***In other***

words, the machine gun must recoil (move backward).

Force necessary to hold the gun in position is equal to the reaction force exerted by the bullets on the gun. This force is also equal to the rate of change of momentum of the bullets. (velocity of bullets before firing U = 0). Hence,

F = rate of change of momentum of 10 bullets.

$$F = \frac{\text{change in momentum of 10 bullets}}{\text{Time}}$$

$$\therefore \quad F = \frac{10\,(m\,V - m\,U)}{t}$$

$$F = \frac{10\,(0.02\times1500 - 0.02\times0)}{1} \quad (t = 1s)$$

$$F = 10 \times 0.02 \times 1500 \qquad \boxed{F = 300\ N}$$

To hold the machine gun in position while firing 10 bullets per sec. ***300 N*** force will be required.

Q.No.5: **A 50 gm. bullet is fired into a 10 kg block that is suspended by a long cord so that it can swing as a pendulum. If the block is displaced so that its center of gravity rises by 10 cm.**

What was the speed of the bullet?

Data:

Mass of the bullet m = 50 gm. =0.050 kg

Mass of the block M = 10 kg.

Height through which C.G rises h=10 cm=0.10 m

Velocity with which bullet collides the block U_1=?

Solution:

Since the gun is initially at rest, therefore, its initial momentum is zero, and initial momentum of bullet is mU_1. After collision the bullet lodges itself into the block and both swing as a pendulum. Let V_2 be the velocity with which the bullet-block system swings immediately after the collision, then total final momentum will be $mV_2 + MV_2$ or $(m + M)V_2$

Applying law of conservation of momentum we get:

Total initial momentum = Total final momentum

$$m\,U_1 = (m + M)\,V_2$$

$$0.05\,U_1 = (0.05 + 10)\,V_2$$

$$\therefore \quad 0.05\,U_1 = 10.05\,V_2 \;\ldots\ldots\ldots(i)$$

K.E of bullet-block system after collision changes into its P.E as its C.G rises.

K.E lost = P.E gained

$$\therefore \quad \tfrac{1}{2}(m + M)\,V_2^2 = (m + M)\,g\,h$$

$$\tfrac{1}{2}(0.05 + 10)V_2^2 = (0.05 + 10)\,9.8\times0.1$$

$$\tfrac{1}{2}\,\cancel{10.05}\,V_2^2 = \cancel{10.05} \times 9.8 \times 0.1$$

$$V_2^2 = 2\times0.98 \quad \text{OR} \quad V_2^2 = 1.96$$

$$\therefore \quad V_2 = \sqrt{1.96} \qquad \boldsymbol{V_2 = 1.4\ m/s.}$$

Immediately after collision the bullet-block system will move with a velocity of 1.4 m/s. On substituting the value of 'V_2' in equation (i) we get:

$$0.05\,U_1 = 10.05\,V_2 \;\ldots\ldots\ldots(i)$$

$$0.05\,U_1 = 10.05 \times 1.4$$

$$\therefore \quad U_1 = \frac{10.05 \times 1.4}{0.05} \qquad \boxed{U_1 = 281.4\ m/s}$$

Speed of the bullet just before collision with the block was ***281.4 m/s.***

Q.No.6: **A 70 gram ball collides with another ball of mass 140 gram. The initial of the first ball is 9 m/s to right while the second ball is at rest. If the collision were perfectly elastic, what would be the velocity of two balls after the collision?**

Data:

Mass of first ball m_1 = 70 g = 0.07 kg

Initial velocity of first ball u_1 = 9 m/s (right)

Mass of second ball m_2=140 g= 0.140 kg

Initial velocity of second ball u_2= 0

Final velocities of both balls v_1 & v_2 =?

Solution:

Velocity v_1 of first after collision is given by:

$$v_1 = \frac{(m_1 - m_2)}{(m_1 + m_2)}\,u_1 + \frac{2\,m_2}{(m_1 + m_2)}\,u_2$$

$$v_1 = \frac{(0.07 - 0.140)}{(0.07 + 0.140)}\times 9 + \frac{2 \times 0.140}{(0.07 + 0.140)}\times 0$$

$$v_1 = -\,\frac{0.07}{0.210}\times 9 + 0 \qquad \boxed{v_1 = -\,3\ m/s}$$

∴ Negative sign shows that, after an elastic collision with heavier second ball, the first ball moves opposite to its initial direction of motion i.e. to ***left***.

Velocity v_2 of second ball after collision is given by:

$$v_2 = \frac{2\,m_1}{(m_1 + m_2)}\,u_1 + \frac{(m_2 - m_1)}{(m_1 + m_2)}\,u_2$$

$$v_2 = \frac{2 \times 0.07}{(0.07 + 0.140)} \times 9 + \frac{(0.140 - 0.07)}{(0.07 + 0.140)}\times0$$

$$v_2 = \frac{2 \times 0.07}{0.21} \times 9 + 0 \qquad \boxed{v_2 = 6\ m/s}$$

Velocity of second ball after collision is ***6 m/s. to right.***

Q.No.7: **A truck weighing 2500 kg and moving with a velocity of 21 m/s collides with a stationary car weighing 1000 kg. The truck**

and car move together after the impact. Calculate their common velocity?

***Data*:**

Mass of the truck $m_1 = 2500$ kg
Initial velocity of the truck $u_1 = 21$ m/s
Mass of the car $m_2 = 1000$ kg
Initial velocity of the car $u_2 = 0$
Final velocity of both $v_1 = v_2 = v = ?$

***Solution*:**

Applying law of conservation of momentum:
Total initial momentum = Total final momentum

$$m\, u_1 + m\, u_2 = m_1\, v_2 + m_2\, v_2$$

Sine after collision both move together, therefore, $v_1 = v_2 = v$

$$m\, u_1 + m\, u_2 = (m_1 + m_2)\, v$$

$$2500\times21 + 1000\times0 = (2500 + 1000)v$$

$$52{,}500 + 0 = 3{,}500\ v$$

$$v = \frac{52{,}500}{3{,}500} \qquad \boxed{v = 15\ m/s}$$

Speed of both after collision is ***15 m/s.***

***Q.No.8*: A stone is dropped from the peak of a hill. It covers a distance of 30 meters in the last second of its motion. Find the height of the peak. (*2013 Karachi Board*)**

***Data*:**

Initial speed $v_i = 0$.
Distance covered during the last second = 30 m.
Height = Total distance covered $S_t = ?$

***Solution*:**

Let 't' be the total time taken by the stone to reach the ground, then height of the cliff or ***in other words***, total distance covered by the stone is given by: $S_t = v_i\, t + \frac{1}{2}\, a\, t^2$

$S_t = 0 \times t + \frac{1}{2} \times 9.8 \times t^2$

$S_t = 4.9\, t^2$ …………………..(i)

Distance covered $S_{(t-1)}$ during (t –1) sec. is given by:

$S_{(t-1)} = v_i\,(t-1) + \frac{1}{2}\, a\,(t-1)^2$

$S_{(t-1)} = 0 \times (t-1) + \frac{1}{2} \times 9.8\times(t-1)^2$

$S_{(t-1)} = 0 + 4.9\,(t^2 - 2t + 1)$

$S_{(t-1)} = 4.9\, t^2 - 9.8t + 4.9$ ….(ii)

But distance covered during the last second is:

$S_t - S_{(t-1)} = 30$ m. Therefore,

$\cancel{4.9\, t^2} - \cancel{4.9\, t^2} + 9.8\, t - 4.9 = 30$

$9.8\, t = 30 + 4.9$

$t = \frac{34.9}{9.8} = 3.56$ second.

Height of the cliff will be equal to the total vertical distance covered (during t sec.):

$S_t = 4.9\, t^2$

$S_t = 4.9\,(3.56)^2 \qquad \boxed{S_t = 62.14\ m}$

Height of the cliff is ***62.14 m.***

***Q.No.9*: A car is waiting at a traffic signal. As it turns green, the car starts ahead with a constant acceleration of 3 m/s². At the same time a bus traveling with a constant speed of 20 m/s overtakes and passes the car.**

(a) How far beyond its starting point the car overtakes the bus?

(b) What will be the velocity of the car at that time? (*2013 Karachi Board*)

***Data*:**

Initial velocity of the car $v_i = 0$
Acceleration of the car $a = 3\,m/s^2$
Constant speed of bus $v = 20$ m/s.
(a) Distance beyond the starting point at which car overtakes the bus $S = ?$
(b) Final velocity of the car $v_f = ?$

***Solution*:**

(a) Let "t" be the time after which car overtakes the bus. Distance covered by the car in time "t": $S_1 = v_i\, t + \frac{1}{2}\, a\, t^2$

$S_1 = 0 \times t + \frac{1}{2} \times 3 \times t^2$

$S_1 = 1.5\, t^2$ …………………..(i)

Distance covered by the bus during the same time: $S_2 = v_i\, t + \frac{1}{2}\, a\, t^2$

$S_2 = 20 \times t$ (bus is travelling with uniform speed, a = 0)

$S_2 = 20\, t$ …………………..(ii)

When the car overtakes the bus at that moment $S_1 = S_2$ OR $1.5\, t^2 = 20\, t$

$1.5\, t = 20$

$t = \frac{20}{1.5} = 13.33$ second

The car overtakes the bus after **13.33 second** at a distance beyond the starting point, given by:

$S_1 = 1.5\, t^2$

$S_1 = 1.5 \times (13.33)^2$

$S_1 = 1.5 \times 177.78$

$$\boxed{S_1 = 266.67\ m}$$

(b) velocity of car when it overtakes the bus:

$v_f = v_i + at$

$v_f = 0 + 3 \times 13.33 \qquad \boxed{v_f = 40\ m/s}$

***Q.No.10*: An electron in a vacuum tube starting from rest is uniformly accelerated by an electric field so that it has a speed of 6×10⁶ m/s after covering a distance of 1.8 cm.**

Find the force acting on the electron.

Take mass of electron as 9.1×10⁻³¹ kg.

Data:

Initial velocity $v_i = 0$.
Final velocity $v_f = 6\times10^6$ m/s
Distance covered $S = 1.8$ cm$= 0.018$ m
Mass of the electron $m = 9.1\times10^{-31}$ kg
Force $F = ?$

Solution

$$2\,a\,S = v_f^2 - v_i^2$$
$$2 \times a \times 0.018 = (6\times10^6)^2 - (0)^2$$
$$0.036\,a = 36\times10^{12}$$
$$a = \frac{36\times10^{12}}{0.036} \qquad \boldsymbol{a = 10^{15}\ m/s^2.}$$

According to second law of motion

$$F = m\,a = 9.1\times10^{-31} \times 10^{15}$$
$$\boxed{F = 9.1\times10^{-16}\ N}$$

Accelerating force (such a force speeds up a body) acting on the electron is ***9.1×10 −16 N***.

Q.No.11: **A bullet having a mass 0.005 kg is moving with a speed of 100 m/s. It penetrates into a bag of sand and is brought rest after moving 25 cm. into the bag. Find the decelerating force on the bullet. Also calculate the time in which it is brought rest.**

Data:

Mass of bullet $m = 0.005$ kg.
Initial speed $v_i = 100$ m/s.
Final speed $v_f = 0$
Distance covered $S = 25$ cm. $= 0.25$ m
Decelerating force $F = ?$
Time taken $t = ?$

Solution:

$$2\,a\,S = v_f^2 - v_i^2$$
$$2 \times a \times 0.25 = (0)^2 - (100)^2$$
$$0.50\,a = -10000$$
$$a = -\frac{10000}{0.50}$$
$$\boldsymbol{a = -20000\ m/s^2.}$$

According to second law of motion \

$$F = m\,a$$
$$F = 0.005 \times -20000$$
$$\boxed{F = -100\ N}$$

Negative sign shows that the force acting on the bullet is decelerating (or retarding) in nature, such a force slows down a body i.e. it produces deceleration. Therefore, the magnitude of the decelerating force acting on the bullet is ***100 N***. Since,

$$v_f = v_i + a\,t$$
$$0 = 100 - 20000\,t$$
$$20000\,t = 100$$
$$t = \frac{100}{20000} \qquad \boxed{t = 0.005\ sec}$$

The bullet takes ***0.005 sec.*** to come to rest.

Q.No.12: **A machine gun fires 10 bullets per second into a target. Each bullet weighs 30 gm. and had a speed of 1500 m/s.**
Find the force necessary to hold the gun in position. (***2025 Karachi Board***)

Data:

Mass of each bullet $m = 30$ gm. $= 0.030$ kg
Number of bullets fired per sec. $= 10$
Velocity of each bullet after firing $V=1500$ m/s
Force necessary to hold the gun in position $F=?$

Solution:

Machine gun and the bullets form one system. Before firing both are at rest, their total initial momentum is zero. To conserve momentum their total momentum after firing must also be zero. This is possible only if the machine gun has equal and opposite momentum (after firing) to that of the bullet. ***In other words***, the machine gun must recoil (move backward).

Force necessary to hold the gun in position is equal to the reaction force exerted by the bullets on the gun. This force is also equal to the rate of change of momentum of the bullets. (velocity of bullets before firing $U = 0$). Hence,

F = rate of change of momentum of 10 bullets.

$$F = \frac{\text{change in momentum of 10 bullets}}{\text{Time}}$$
$$\therefore \quad F = \frac{10\,(m\,V - m\,U)}{t}$$
$$F = \frac{10\,(0.03\times1500 - 0.03\times0)}{1} \quad (t = 1s)$$
$$F = 10 \times 0.03 \times 1500 \qquad \boxed{F = 450\ N}$$

To hold the machine gun in position while firing 10 bullets per sec. ***450 N*** force will be required.

Q.No.13: **A 100 gm. bullet is fired from a 10 kg. gun with a speed of 1000 m/s.**
What is speed of recoil of the gun?

Data: (***2026 Karachi Board***)

Mass of bullet $m = 100$ gms $= 0.1$kg
Mass of the gun $M = 10$ kg.
Speed of the bullet $V_1 = 1000$ m/s.
Speed of the gun $V_2 = ?$.

Solution:

According to law of conservation of momentum:

Total initial momentum = Total final momentum

Since the gun and the bullet both are initially at rest, therefore, total initial momentum is zero. Applying law of conservation of momentum we get:

$$0 = m\,V_1 + M\,V_2$$

$$0 = 0.1 \times 1000 + 10\,V_2$$

$$10\,V_2 = -\,100$$

$$\therefore \quad V_2 = -\,\frac{100}{10} \qquad \boxed{V_2 = -\,10\ m/s.}$$

Negative sign shows that after firing the bullet, the gun moves backward (opposite to the direction of motion of the bullet). This backward movement of the gun after firing is called recoil of the gun.

Do you know that.......

There are **four** **FUNDAMENTAL FORCES** in nature:

- Strong force.
- Electromagnetic force.
- Gravitational force.
- Weak force.

- **Strong force,** this is the strongest force in nature, it keeps nucleons (protons and neutrons) togather in a nucleus. It is a **short range** force. Its range is even shorter than diameter of a heavy nucleus.
  This force is about **100 times stronger than the electromagnetic force**.
  Field particles **Gluons** are exchanged in this force.

- **Electromanetic force,** this force is basically an interaction between electric and magnetic fields. Electromagnetic force is responsible for the formation of atoms and molecules, in general whole chemistry is due to this force.
  Field particles **photons** are exchanged in this force.
  This force is about **10^{36} times stronger than the gravitational force**.

- **Gravitational force,** exists between all bodies having mass. It is a **long range** force.
  Field particles **Gravitons** are exchanged in this force.

- **Weak force**, Weak force exists during certain nuclear reactions such as in beta decay. This force is responsible for the stability of atoms. It is a **short range** force.