UNIT - 1
LAWS OF MOTION

I. Choose the correct answer

1. Inertia of a body depends on
   a) weight of the object
   b) acceleration due to gravity of the planet
   c) mass of the object
   d) both a & b
2. Impulse is equals to (or) Impulse is the **[PTA – 1]**
   a) rate of change of momentum
   b) rate of force and time
   c) change of momentum
   d) rate of change of mass
3. Newton's III law is applicable
   a) for a body is at rest
   b) for a body in motion
   c) both a & b
   d) only for bodies with equal masses
4. Plotting a graph for momentum on the Y-axis and time on X-axis. Slope of momentum-time graph gives
   a) Impulsive force b) Acceleration **c) Force** d) Rate of force
5. In which of the following sport the turning of effect of force used
   a) swimming b) tennis **c) cycling** d) hockey
6. The unit of 'g' is m s^{-2}. It can be also expressed as
   a) cm s^{-1} **b) N kg^{-1}** c) N m^2 kg^{-1} d) cm^2 s^{-2}
7. One kilogram force equals to
   a) 9.8 dyne b) 9.8×10^4 N **c) 98×10^4 dyne** d) 980 dyne
8. The mass of a body is measured on planet Earth as M kg. When it is taken to a planet of radius half that of the Earth then its value will be _____ kg.
   a) 4 M b) 2M c) $\frac{M}{4}$ **d) M**
9. If the Earth shrinks to 50% of its real radius its mass remaining the same, the weight of a body on the Earth will
   a) decrease by 50% b) increase by 50% c) decrease by 25% **d) increase by 300%**
10. To project the rockets which of the following principle(s) is/are required? **[SEP – 2021, MDL – 19]**
    a) Newton's third law of motion
    b) Newton's law of gravitation **[AUG-22]**
    c) law of conservation of linear momentum
    d) Both a and c

II. Fill in the blanks

1. To produce a displacement **force** is required.
2. Passengers lean forward when sudden brake is applied in a moving vehicle. This can be explained by **inertia of motion.**
3. By convention, the clockwise moments are taken as **negative** and the anticlockwise moments are taken as **positive.**
4. **Gears** is used to change the speed of car.
5. A man of mass 100 kg has a weight of **980 N** at the surface of the Earth.

III. True or False. If false correct it.

1. The linear momentum of a system of particles is always conserved. **[False]**

   ***The linear momentum of a system of particles is conserved, when **no external force is applied**.*

2. Apparent weight of a person is always equal to his actual weight. **[False]**

   Apparent weight of a person is equal to his actual weight **when he is at rest.*

3. Weight of a body is greater at the equator and less at the polar region. **[False]**

   ***Weight of a body is **less** at the equator and **greater** at the polar region.*

4. Turning a nut with a spanner having a short handle is so easy than one with a long handle. **[False]**

   Turning a nut with a spanner having a **long handle is so easy than one with a **short** handle.*

5. There is no gravity in the orbiting space station around the Earth. So, the astronauts feel weightlessness. **[False]**

   ***Astronauts and orbiting space station are under free fall with same acceleration**. So the astronauts feel weightlessness.*

IV. Match the following

[PTA – 1]

Column I	Column II	Answer
a) Newton's I law	Propulsion of a rocket	**a) Stable equilibrium of a body**
b) Newton's II law	Stable equilibrium of a body	**b) Law of force**
c) Newton's III law	Law of force	**c) Flying nature of bird**
d) Law of conservation of Linear momentum	Flying nature of bird	**d) Propulsion of a rocket**

V. Assertion & Reasoning

Mark the correct choice as

(a) If both the assertion and the reason are true and the reason is the correct explanation of assertion.
(b) If both the assertion and the reason are true, but the reason is not the correct explanation of the assertion.
(c) Assertion is true, but the reason is false. (d) Assertion is false, but the reason is true.

1. **Assertion:** The sum of the clockwise moments is equal to the sum of the anticlockwise moments.
   Reason : The principle of conservation of momentum is valid if the external force on the system is zero.

   Ans. (b) ***Both the assertion and the reason are true, but the reason is not the correct explanation of the assertion.***

2. **Assertion:** The value of 'g' decreases as height and depth increases from the surface of the Earth.
   Reason : 'g' depends on the mass of the object and the Earth.

   Ans. (c) ***Assertion is true, but the reason is false.***

VI. Answer briefly.

1. Define inertia. Give its classification. **[AUG - 2022]**

The inherent property of a body to resist any change in its state (rest or motion), unless it is influenced by an external unbalanced force is called inertia.

Classification of Inertia :

- ❖ Inertia of rest
- ❖ Inertia of motion
- ❖ Inertia of direction

2. Classify the types of force based on their application. **[AUG - 2022]**

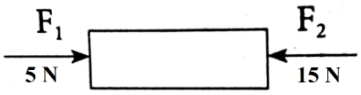
Types of Forces:

(i) Like parallel force (ii) Unlike parallel force

3. If a 5 N and a 15 N forces are acting opposite to one another. Find the resultant force and the direction of action of the resultant force.

Given , $F_1 = 5N$ $F_2 = 15\ N$

$F_{net} = F_2 - F_1 = 15 - 5 = 10\ N.$



∴ Magnitude is 10 N and direction is along 15 N force.

4. Differentiate mass and weight. **[MAY - 2022]**

Mass	Weight
1. It measures the quantity of matter.	1. It measures the gravitational force on a body.
2. SI unit is Kilogram (Kg).	2. SI unit is Newton (N).
3. Fundamental quantity.	3. Derived quantity.
4. Scalar quantity.	4. Vector quantity.

5. Define moment of a couple.

It is the product of any one of the forces and the perpendicular distance between the line of action of two forces. Its SI unit is Nm.

$$\mathbf{M = F \times S}$$

6. State the principle of moments.

At equilibrium, the algebraic sum of the moments of all the individual forces about any point is equal to zero.

Moment of clockwise direction = Moment of anticlockwise direction

7. State Newton's second law. **[MDL – 19, MAY - 2022]**

The force acting on a body is directly proportional to the rate of change of linear momentum of the body and the change in momentum takes place in the direction of the force.

$$\mathbf{F} = \boldsymbol{ma}$$

8. Why a spanner with a long handle is preferred to tighten screws in heavy vehicles?

- ❖ The turning effect is more when the distance between line of action and axis of rotation is more.
- ❖ Hence, the spanner has a long handle is preferred to tighten screws in heavy vehicles.

9. While catching a cricket ball the fielder lowers his hands backwards. Why?

- ❖ To increase the time of contact.
- ❖ To reduce the impulse and the pain.

10. How does an astronaut float in a space shuttle?

- ❖ Astronauts are not floating but falling freely around the Earth due to their huge orbital velocity.
- ❖ Since space station and astronauts have equal acceleration, they are under free fall condition.

VIII. Answer in detail

1. What are the types of inertia? Give an example for each type. **[AUG – 2022, PTA – 3]**

a) Inertia of rest: It is the resistance of a body to change its state of rest.

Ex : *When we shake a tree, leaves and fruits fall down.*

b) Inertia of motion : It is the resistance of a body to change its state of motion.

Ex : *An athlete runs some distance before jumping for a longer and higher jump.*

c) Inertia of direction : It is the resistance of a body to change its direction of motion.

Ex : *When car turns, we lean sideways.*

2. State Newton's laws of motion. **[AUG – 2022, SEP – 2021]**

a) Newton's First law :

Every body continues to be in its state of rest or the state of uniform motion along a straight line unless some external force acts upon it.

b) Newton's second law :

The force acting on a body is directly proportional to the rate of change of linear momentum of the body and the change in momentum takes place in the direction of the force. $\mathbf{F} = \boldsymbol{ma}$

c) Newton's third law :

For every action, there is an equal and opposite reaction. $\mathbf{F_B = - F_A}$

3. Deduce the equation of a force using Newton's second law of motion. (or) A body of mass m is initially moving with a velocity u. When a force 'F' acts on the body it picks up velocity 'v' in 't second' so that the acceleration 'a' is produced. Using this data derive the relation between the force, mass and acceleration. **[PTA – 5]**

Newton's second law of motion :

The force acting on a body is directly proportional to the rate of change of linear momentum of the body and the change in momentum takes place in the direction of the force.

Derivation for the equation of force:

Let, m → mass of a moving body u → initial velocity

F → unbalanced external force v → final velocity after a time interval 't'

Initial momentum $P_i = mu$,

Final momentum $P_f = mv$

Change in momentum, $\Delta P = P_f - P_i = mv - mu$

$$F \propto \frac{Change\ in\ momentum}{time}$$

$$F = \frac{mv-mu}{t} = m\left[\frac{v-u}{t}\right];$$

$$F = ma \quad (\because a = \frac{v-u}{t})$$

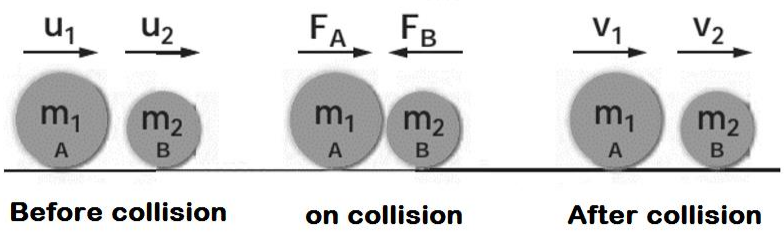
Force = mass × acceleration

4. State and prove the law of conservation of linear momentum. **[MDL – 19]**

Law of Conservation of momentum:

There is no change in the linear momentum of a system of bodies as long as no net external force acts on them.

Proof:



- Let A and B with mass m_1, m_2 move in straight line with velocity u_1, u_2 such that $u_1 > u_2$.
- At 't second', they have a collision.
- After collision, A and B move in same straight line with velocity v_1 and v_2.

$F_A = \frac{m_2(v_2 - u_2)}{t}$ -------- (1) $F_B = \frac{m_1(v_1 - u_1)}{t}$ -------- (2)

By Newton's third law, $F_B = -F_A$

$$\frac{m_1(v_1 - u_1)}{t} = -\frac{m_2(v_2 - u_2)}{t}$$

$$m_1(v_1 - u_1) = -m_2(v_2 - u_2)$$

$$m_1v_1 - m_1u_1 = -m_2v_2 + m_2u_2$$

$$\boxed{m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2}$$

Hence the law is proved.

5. Describe rocket propulsion. **[AUG – 2022, SEP – 2020, PTA – 4]**

Principle: Law of conservation of linear momentum and Newton's III law of motion.

- When rocket is fired, fuel is burnt and hot gas is ejected with high speed & huge momentum.
- To balance this momentum, an equal & opposite force is produced, projecting rocket forward.
- In motion, mass of rocket decreases, until the fuel is completely burnt.
- There is no net external force acting on it, and so linear momentum is conserved.
- Mass of rocket decreases with altitude. This increases the velocity and reaches escape velocity, which is sufficient to just escape from the gravitational pull of Earth.

6. State the universal law of gravitation and derive its mathematical expression.

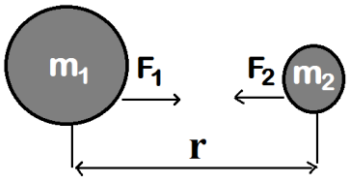
Newton's Universal Law of gravitation :

- Gravitational force is directly proportional to the product of masses and inversely proportional to the square of the distance between the center of these masses.
- The direction of the force acts along the line joining the masses.

Mathematical Expression of Universal Law of gravitation :

Let, m_1 and m_2 be the masses of two bodies A and B

Let r be the distance between them.



$$F \propto \frac{m_1m_2}{r^2} \Rightarrow F = G\frac{m_1m_2}{r^2}$$

Where Universal gravitational constant, $G = 6.674 \times 10^{-11} Nm^2kg^{-2}$

7. Give the applications of universal law of gravitation.

i) Helps to calculate mass and radius of earth, acceleration due to gravity, etc.
ii) Helps in discovering new stars and planets.
iii) Helps to predict the path of astronomical bodies.
iv) Helps to maintain the motion of planets around the sun and moon around the earth.
v) Helps to maintain water flow in rivers and seas.

VII. Solve the given problems

1. Two bodies have a mass ratio of 3:4. The force applied on the bigger mass produces an acceleration of 12 m s^{-2}. What could be the acceleration of the other body, if the same force acts on it?

Given : $m_1 : m_2 = 3 : 4$; $F_1 = F_2$ Let m_2 be bigger, then $a_2 = 12\ ms^{-2}$

Solution : $F_1 = F_2$

$m_1 a_1 = m_2 a_2$ $(\because F = ma)$

$a_1 = \frac{m_2}{m_1}\ a_2 = \frac{4}{3} \times 12 = 16\ ms^{-2}$

∴ Acceleration, a_1 is $\mathbf{16\ ms^{-2}}$

2. A ball of mass 1 kg moving with a speed of 10 m s^{-1} rebounds after a perfect elastic collision with the floor. Calculate the change in linear momentum of the ball.

Given : m = 1 kg, u = 10 m s^{-1},

Solution : It is perfect elastic collision, ball rebounds with same speed but in opposite direction ∴ v = −10 m s^{-1}

$\Delta p = mv - mu = 1 \times (-10) - 1 \times (10)$

$= -10 - 10$

$= -20$ kg m s^{-1}

∴ Change in Linear momentum is $\mathbf{20 kg ms^{-1}}$

3. A mechanic unscrew a nut by applying a force of 140 N with a spanner of length 40 cm. What should be the length of the spanner if a force of 40 N is applied to unscrew the same nut?

Given : $F_1 = 140\ N$, $d_1 = 40\ cm$;

$F_2 = 40\ N$, $d_2 = ?$

Solution : Moment of couple is same,

$F_1 d_1 = F_2 d_2$

$d_2 = \frac{F_1 d_1}{F_2} = \frac{40 \times 140}{40} = 140\ cm$

∴ Length should be 140 cm / 1.4 m.

4. The ratio of masses of two planets is 2:3 and the ratio of their radii is 4:7. Find the ratio of their accelerations due to gravity.

Given : $m_1 : m_2 = 2 : 3$; $R_1 : R_2 = 4 : 7$; $g_1 : g_2 = ?$

Solution : $g_1 = \frac{GM_1}{R_1^2}$ ---- (1) $g_2 = \frac{GM_2}{R_2^2}$ ------ (2)

Eqn (1) ÷ (2) ⇒ $\frac{g_1}{g_2} = \frac{\frac{GM_1}{R_1^2}}{\frac{GM_2}{R_2^2}} = \frac{GM_1}{R_1^2} \times \frac{R_2^2}{GM_2} = \frac{M_1}{M_2} \times \frac{R_2^2}{R_1^2}$

$\frac{g_1}{g_2} = \frac{2}{3} \times \frac{7^2}{4^2} = \frac{2}{3} \times \frac{49}{16} = \frac{49}{24}$

∴ $g_1 : g_2 = 49 : 24$

IX. Hot Questions

1. Two blocks of masses 8 kg and 2 kg respectively lie on a smooth horizontal surface in contact with one other. They are pushed by a horizontally applied force of 15 N. Calculate the force exerted on the 2 kg mass.

Given : $m_1 = 8$ kg, $m_2 = 2$ kg, Force, F = 15 N

Solution : $F = ma = (m_1 + m_2)\ a$

$a = \frac{F}{m_1 + m_2} = \frac{15}{8+2} = \frac{15}{10} = 1.5\ ms^{-2}$

Force on 2 kg mass, $m = 2$ kg, $a = 1.5\ ms^{-2}$

$F = ma = 2 \times 1.5 = 3N$

∴ Force on 2kg mass is **F = 3N**

2. A heavy truck and bike are moving with the same kinetic energy. If the mass of the truck is four times that of the bike, then calculate the ratio of their momenta. (Ratio of momenta = 2 : 1)

Given : Let, Mass of bike $= m_B$; Mass of truck $= m_T$; $\frac{m_T}{m_B} = 4$

Solution : Kinetic Energy $= \frac{1}{2}\, mv^2$

K.E of truck = K.E of bike

$$\frac{1}{2} m_T v_T^2 = \frac{1}{2} m_B v_B^2$$

$$\left(\frac{V_B}{V_T}\right)^2 = \frac{m_T}{m_B} = 4$$

$$\frac{V_B}{V_T} = 2 \Rightarrow \frac{V_T}{V_B} = \frac{1}{2}$$

Ratio of their momentum is, $\frac{p_T}{p_B} = \frac{m_T V_T}{m_B V_B} = \frac{4}{2} = 2$

∴ Ratio of their momentum is 2 : 1.

3. "Wearing helmet and fastening the seat belt is highly recommended for safe journey" Justify your answer using Newton's laws of motion.

Wearing helmet is highly recommended for safe journey:

- ❖ When you fall from a bike, you fall with a force equal to your mass and acceleration of the bike (Newton's second law).
- ❖ An equal and opposite force is exerted on you (Newton's third law).
- ❖ Wearing helmet will reduce the effect of force and saves us from fatal head injuries.
- ❖ So, it is important to wear helmet for the safe journey.

Fastening the seat belt is highly recommended for safe journey:

- ❖ When vehicle stops suddenly, by law of inertia, we will be in motion until a force act on us.
- ❖ If we don't wear a seat belt, we would get hurt during this motion.
- ❖ If we wear a seat belt, the seat belt gives us an unbalanced force that stops us.