PETIT SEMINAIRE HIGHER SECONDARY SCHOOL – PUDUCHERRY

UNIT – 1 LAWS OF MOTION

STD: X SELF – EVALUATION

I. Choose the best answer:

1. Inertia of a body depends on - **(C) Mass of the object**
2. Impulse is equals to - **(C) Change of momentum**
3. Newton's III law is applicable - **(C) Both a & b**
4. Plotting a graph for momentum on the Y – axis and time on X – axis. Slope of momentum – time graph gives - **(C) Force**
5. In which of the following sport the turning of effect of force used - **(C) Cycling**
6. The unit of 'g' is m s^{-2}. It can also expressed as - **(B) N kg^{-1}**
7. One kilogram force equals to - **(C) 98 x 10^4 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.
   - **(D) M**
   (Hint: when radius of the earth is reduced to half of its present value, with no change in the mass)
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 - **(D) increase by 300%**
10. To project the rockets which of the following principle (s) is / (are) required? - **(D) Both a & c**

II. Fill in the blanks:

1. To produce a displacement **Force (or) unbalanced force** is required.
2. Passengers lean forward when sudden brake is applied in a moving vehicle. This can be explained by **Newton's I law (inertia of motion)**
3. By convention, the clockwise moments are taken as **Negative** and the anticlockwise moments are taken as **Positive.**
4. **Moment of force (or) Torque (Gear)** 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. State whether the following statements are true or false. Correct the statement if it is false:

1. The linear momentum of a system of particle is always conserved. - **False**

Correct statement: In the absence of external force, the linear momentum of a system of particle is always conserved.

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

Correct statement: When a person move upwards and downwards apparent weight change.

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

Correct statement: Weight of the body is lesser 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**

Correct statement: 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**

Correct statement: There is free fall in the orbiting space station around the Earth. So the astronauts feel weightlessness

IV. Match the following:

S.No	Column 1	Column 2
a	Newton's I law	Stable equilibrium of a body
b	Newton's II law	Law of force
c	Newton's III law	Flying nature of bird
d	Law of conservation of linear momentum	Propulsion of a rocket.

V. Assertion & Reasoning:

1. **Assertion:** The sum of the clockwise moments is equal to the sum of the anti clockwise moments.

Reason: The principle of conservation of momentum is valid if the

external force on the system is zero.

(b) If 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.

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

VI. Answer briefly:

1. Define inertia. Give its classification?

   The inherent property of a body to resist any change in its state of rest or the state of uniform motion, unless it is influenced upon by an external unbalanced force, is known as 'inertia'.

   Classification:

   (i) Inertia of rest, (ii) Inertia of motion, (iii) Inertia of direction.

2. Classify the types of force based on their application?

   Types of force:

   (i) Like parallel forces:

   Two or more forces of equal or unequal magnitude acting along the same direction, parallel to each other.

   (ii) Unlike parallel forces:

   If two or more equal forces or unequal forces act along opposite directions parallel to each other.

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: $F_1 = 5N$; $F_2 = 15N$

   Two unequal forces acting opposite to one other. Therefore,

   Resultant force (F_{net}) = $F_2 - F_1$

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

   The F_{net} is directed along the greater force (F_2).

4. Differentiate mass and weight?

S.NO	Mass	Weight
1	Fundamental quantity	Derived quantity
2	It is the amount of matter	It is the gravitational pull

	contained in a body.	acting on the body.
3	Its unit is kilogram	Its unit is newton.
4	Remains the same.	Varies from place to place.
5	It is measured using physical balance	It is measured using spring balance.

5. Define moment of a couple?

Moment of a couple is defined as the product of any one of the forces and the perpendicular distance between the line of action of two forces. Rotating effect of a couple is known as moment of a couple. S.I unit is Nm.

$$M = F \times S.$$

6. State the principle of moments?

When a number of like or unlike parallel forces act on a rigid body and the body is in equilibrium, then the algebraic sum of the moments in the clockwise directions is equal to the algebraic sum of the moments in the anticlockwise direction. Or

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

7. State 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.

$$F \alpha \frac{mv-mu}{t}$$

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

- The turning effect of a force is called "moment of force".
- The turning effect of a body depends upon the perpendicular distance of the line of action of the applied force from the axis of rotation.
- Moment of force = force x perpendicular distance (F x d).
- The handle of the spanner is long; the force requires turning the body is less. If 'd' is large, the moment of force is also large.

Hence it is easier to rotate the object (nut).

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

In cricket, a fielder pulls back his hands while catching the ball. He experiences a smaller force for a longer interval of time to catch the ball, resulting in a lesser impulse on his hands.

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. Hence, both the astronauts and the space station are in the state of weightlessness.

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 ms^{-2}. What could be the acceleration of the other body, if the same force acts on it.

Mass ratio $m_1 : m_2 = 3 : 4$.

$$\frac{m_1}{m_2} = \frac{3}{4}$$

The force applied on the bigger mass (m_2 = 4 kg) produces an acceleration $a_2 = 12\ ms^{-2}$. Therefore, m_1 = 3 kg, a_1 =?

Same force, $F_1 = F_2$

$m_1 a_1 = m_2 a_2$

$$a_1 = \frac{m_2 a_2}{m_1}$$

$$a_1 = \frac{4 \times 12}{3} = \frac{48}{3} = 16\ ms^{-2}.$$

The acceleration of the other body is 16 ms^{-2}.

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

Mass of the ball (m) = 1 kg, initial velocity (u) = 10 ms^{-1}; final velocity = -10 ms^{-1} (rebounds)

Change in momentum (Δp) = mv – mu

$$\Delta p = \{1 \times (-10)\} - (1 \times 10) = -20\ kg\ ms^{-1}$$

$\Delta p = -20\ kgms^{-1}$.

Change in momentum of the ball is 20 $kgms^{-1}$ (Negative sign just indicates the direction of momentum).

3. A mechanic unscrews a nut by applying a force 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?

   Equating the torque (moment of force) in both the cases.

$$F_1 l_1 = F_2 l_2$$

$$140 \times 40 = 40 \times l_2$$

$$l_2 = \frac{140 \times 40}{40}$$

$$l_2 = 140\ cm\ (or)\ 1.4\ m.$$

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.

$$g_1 = \frac{G M_1}{R_1^2} \quad ; g_2 = \frac{G M_2}{R_2^2}$$

$$g_1 / g_2 = \frac{M_1}{R_1^2} \times \frac{R_2^2}{M_2}$$

$$= \frac{2}{3} \times \left(\frac{7}{4}\right)^2$$

$$= \frac{49}{24}$$

$$g_1 : g_2 = 49 : 24$$

VIII. Answer in detail:

1. What are the types of inertia? Give an example for each type?

   There are three types of inertia. They are:

   - Inertia of rest: The resistance of a body to change its state of rest. Ex: when you vigorously shake the branches of a tree, some of the leaves and fruits are detached and they fall down.
   - Inertia of motion: The resistance of a body to change its state of motion. Ex: An athlete runs some distance before jumping. Because, this will help him jump longer and higher.
   - Inertia of direction: The resistance of a body to change its direction of motion. Ex: when you make a sharp turn while driving

a car, you tend to lean sideways.

2. State Newton's laws of motion?

Newton's First law: It states that everybody continues to be in its state of rest or the state of uniform motion along a straight line unless it is acted upon by some external forces.

Newton's Second law: It states that 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.

Newton's Third law: It states that for every action, there is an equal and opposite reaction. They always act on two different bodies.

3. Deduce the equation of a force using Newton's second law of motion.

Statement: It states that 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.

Proof:

This law helps us to measure the amount of force. So it is called as 'law of force'. Let 'm' be the mass of a moving body, moving along a straight line with an initial speed 'u.' After a time interval of 't', the velocity of the body changes to 'v' due to the impact of an unbalanced external force F.

Initial momentum of the body $P_i = mu$

Final momentum of the body $P_f = mv$

Change in momentum $\Delta P = P_f - P_i$

$= mv - mu$

By Newton's second law of motion,

Force, F α rate of change of momentum

F α change in momentum / time

$$F \alpha \frac{mv-mu}{t}$$

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

Here, k is the proportionality constant, k = 1 in all systems of units. Hence,

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

Since, acceleration = change in velocity / time, $a = (v - u) / t$.

hence, we have

$F = m \times a$

Force = mass x acceleration.

No external force is required to maintain the motion of a body moving with uniform velocity. When the net force acting on a body is not equal to zero, then definitely the velocity of the body will change.

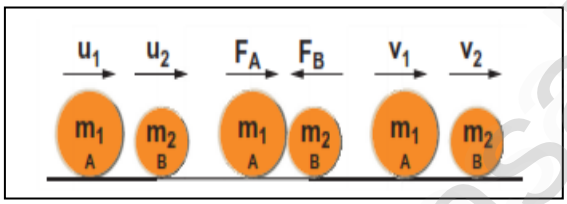
4. State and prove the law of conservation of linear momentum?

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

Or

In the absence of external unbalanced force, the total momentum of a system of objects remains unchanged.

Proof:



Let two bodies A and B having masses m_1 and m_2 move with initial velocity u_1 and u_2 in a straight line. Let the velocity of the first body be higher than that of the second body. i.e., $u_1 > u_2$. During an interval of time t second, they tend to have a collision. After the impact, both of them move along the same straight line with a velocity v_1 and v_2 respectively.

Force on body B due to A,

$$F_B = m_2 (v_2 - u_2) / t$$

Force on body A due to B,

$$F_A = m_1 (v_1 - u_1) / t$$

By Newton's III law of motion,

Action force = Reaction force

$F_A = F_B$

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

$m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2$

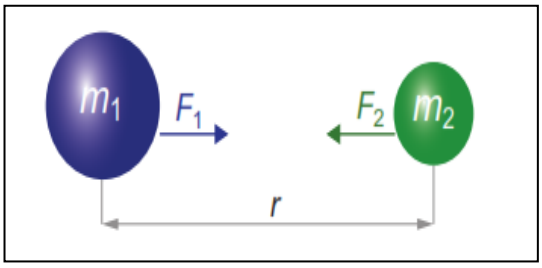
The above equation confirms in the absence of an external force, the algebraic sum of the momentum after collision is numerically

equal to the algebraic sum of the momentum before collision.

5. Describe the Rocket propulsion?
   - Propulsion of rockets is based on the law of conservation of linear momentum as well as Newton's Third law of motion.
   - Rockets are filled with a fuel (either liquid or solid) in the propellant tank.
   - When the rocket is fired, this fuel is burnt and a hot gas is ejected with a high speed from the nozzle of the rocket, producing a huge momentum.
   - To balance this momentum, an equal and opposite reaction force is produced in the combustion chamber, which makes the rocket project forward.
   - While in motion, the mass of the rocket gradually decreases, until the fuel is completely burnt out.
   - Since there is no net external force acting on it, the linear momentum of the system is conserved.
   - The mass of the rocket decreases with altitude, which results in the gradual increase in velocity of the rocket.
   - At one stage, it reaches a velocity, which is sufficient to just escape from the gravitational pull of the earth. This velocity is called escape velocity.
6. State the universal law of gravitation and derive its mathematical expression?

   Statement: It states that every particle of matter in this universe attracts every other particle with a force. This force is directly proportional to the product of their masses and inversely proportional to the square of the distance between the centers of these masses. The direction of the force acts along the line joining the masses.

   Derivation:



Force between the masses is always attractive and it does not depend on the medium where they are placed.

Let m_1 and m_2 be the masses of two bodies A and B placed r metre apart in space.

Force $F \alpha m_1 \times m_2$

$F \alpha 1/r^2$

On combining the above two expressions

$$F \alpha \frac{m_1 \times m_2}{r^2}$$

$$F = \frac{G m_1 m_2}{r^2}$$

Where G is the universal gravitational constant. Its value in SI unit is 6.674×10^{-11} N m^2 kg^{-2}.

7. Give the applications of universal law of gravitation?

Applications:

- Dimensions of the heavenly bodies can be measured using the gravitation law. Mass of the earth, radius of the earth, acceleration due to gravity, etc. can be calculated with a higher accuracy.
- Helps in discovering new stars and planets.
- One of the irregularities in the motion of stars is called 'wobble' lead to the disturbance in the motion of a planet nearby. In this condition the mass of the star can be calculated using the law of gravitation.
- Helps to explain germination of roots is due to the property of geotropism which is the property of a root responding to the gravity.
- Helps to predict the path of the astronomical bodies.

IX. HOT Question:

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.

m_1 = 8 kg; m_2 = 2 kg; Horizontal applied force = 15 N;

According to Newton's Second law, F = ma

$$F = (m_1 + m_2)\, a$$

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

Force exerted on the 2 kg mass

$$m = 2\ kg;\ a = 1.5\ ms^{-2}$$

$$F = m \times a = 2 \times 1.5 = 3\ N$$

The force exerted on the 2 kg mass is F = 3 N.

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.

Given:

Mass of bike = m_1; mass of truck = $m_2 = 4\, m_1$

Kinetic energy = $\frac{1}{2} mv^2 = \frac{1}{2} mv^2 \times \frac{m}{m}$

$$= \frac{1}{2} \times \frac{m^2v^2}{m} = \frac{1}{2} \frac{p^2}{m}$$

Truck and bike have same kinetic energy $\Rightarrow k_1 = k_2$

$$\frac{1}{2}\frac{p_1^2}{m_1} = \frac{1}{2} \frac{p_2^2}{m_2}$$

$$\frac{p_1^2}{m_1} = \frac{p_2^2}{m_2}$$

$$\frac{p_1^2}{p_2^2} = \frac{m_1}{m_2}$$

$$\frac{p_1^2}{p_2^2} = \frac{m_1}{4m_1} = \frac{1}{4}$$

$$\frac{p_1}{p_2} = \frac{1}{2}$$

$$P_1 : p_2 = 1 : 2$$

The ratio of their momenta = 1 : 2

3. “Wearing helmet and fastening the seat belt is highly recommended for safe journey”. Justify your answer using Newton’s law of motion.

   Wearing a helmet:

   - When a person falls from the bike he exerts a force equal to product of mass of the person and acceleration of the bike (Newton’s II law).
   - According to Newton’s III law, In turn the ground offers and equal and opposite force on the person, which will produce large damage.
   - In order to minimize damages the person must wear helmet.

   Fastening of seat belt:

   - It will not allow a person to move from seat why the vehicle comes to rest suddenly by applying brake or by having some accidents.
   - This is due to inertia of motion (Newton’s I law).
   - When the speeding vehicle stops suddenly the lower part in contact with the seat stops while the upper part of the body tends to maintain its uniform motion.
   - Hence the person will turn forward and obtain injuries. In order to avoid this, fastening of seat belt is important.