2025-26

Physics 9

Comprehensive Notes with Short Questions, Long Questions, MCQs, and Problems

Prepared By:

Muhammad Tayyab

Govt Christian High School Daska

1. Define dynamics?

***Dynamics** deals with the **forces** that produce changes in the motion of bodies.*

**** 2. How is force commonly defined? OR What kind of changes in motion may be produced by a force?**

*A force is a **push** or **pull** that can start, stop, or change the magnitude and direction of a body's velocity.*

For example, opening a door (pushing or pulling), lifting and moving a wheelbarrow (ایک پہیہ ریڑھی).

**** 3. What are contact and non-contact forces? Explain with examples. OR Give 5 examples of contact forces.**

Contact Forces: *A contact force is a force that is exerted by one object on the other at the point of contact. Applied forces (push, pull, and twist) are contact forces.*

Some examples of contact forces are:

(i) **Friction:** It is the force that resists motion when the surface of one object comes in contact with the surface of another.

(ii) **Drag:** The drag force is the resistant force caused by the motion of a body through a fluid. It acts opposite to the relative motion of any object moving with respect to surrounding fluid.

(iii) **Thrust:** It is an upward force exerted by a liquid on an object immersed in it. For example, when we try to immerse an object in water, we feel an upward force exerted on the object.

(iv) **Normal Force:** It is the force of reaction exerted by the surface on an object lying on it. This force acts outward and perpendicular to the surface.

(v) **Air Resistance:** It is the resistance (opposition) offered by air when an object falls through it.

(vi) **Tension Force:** It is the force experienced by a rope when a person or load pulls it.

(vii) **Elastic Force:** It is a force that brings certain materials back to their original shape after being deformed. Examples include rubber bands, springs, and trampolines.

Non-contact Forces: *A non-contact force is defined as the force between two objects which are not in physical contact.*

The non-contact forces can work from a distance, and there is always a field linked with a non-contact force. Due to this property, non-contact forces are also called **field forces**.

Some examples of non-contact forces are:

(i) Gravitational Force: It is an attractive force that exists among all bodies which have mass. For example, when an apple falls from a tree, it is the gravitational force of the Earth that pulls it downward. The gravitational force is given by Newton's Law of Gravitation:

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

where m_1 and m_2 are the masses, r is the distance between them, and $G = 6.673 \times 10^{-11}\ Nm^2kg^{-2}$ is the gravitational constant.

(ii) Electrostatic Force: An electrostatic force acts between two charged objects. Opposite charges attract each other and similar charges repel each other.

(iii) Magnetic Force: It is a force which a magnet exerts on other magnets and magnetic materials like iron, nickel, and cobalt. Magnetic force between the poles of two magnets can be either attractive or repulsive.

(iv) Strong and Weak Nuclear Forces: These are non-contact forces acting between the subatomic particles inside the nucleus of an atom.

4. What are the four fundamental forces in nature? Explain each with examples.

There are four fundamental forces in nature, and every force we observe falls under one of these categories:

(i) Gravitational Force
(ii) Electromagnetic Force
(iii) Strong Nuclear Force
(iv) Weak Nuclear Force

(i) Gravitational Force: The gravitational force is an attractive force that exists between all objects with mass. Although it is the **weakest** among the four fundamental forces, it has an **infinite range** and governs large-scale structures like planets, stars, and galaxies.

For example, it is the force that pulls an apple to the ground and keeps planets in orbit around the Sun.

(ii) Electromagnetic Force: The electromagnetic force causes the interaction between **electrically charged particles**. Both electrostatic and magnetic forces fall under this category. It is a long-range force and is much stronger than gravitational and weak nuclear forces.

Example: A moving magnet produces an electric current. The electromagnetic force causes chemical reactions, binds atoms and molecules, and is responsible for friction at a macroscopic level. The regions where these forces act are known as **electromagnetic fields**.

(iii) Strong Nuclear Force: The strong nuclear force is the strongest of the four forces but acts only over a very short range ($10^{-14}\ meters$). It holds the atomic nucleus together by binding protons and neutrons, overcoming the **repulsive electromagnetic force** between positively charged protons.

If the distance between nucleons (protons and neutrons) exceeds this range, the strong nuclear force ceases to act.

(iv) Weak Nuclear Force: The weak nuclear force is responsible for certain types of nuclear reactions, such as **beta decay**. For example, during $\beta - decay$,

M. Tayyab

a neutron transforms into a proton, releasing a $\beta - particle$ (electron) and an **antineutrino**.

The weak nuclear force has a short range ($10^{-17}\ meters$).

It is stronger than gravitational force but weaker than the electromagnetic force.

It plays a crucial role in radioactive decay and nuclear fusion processes.

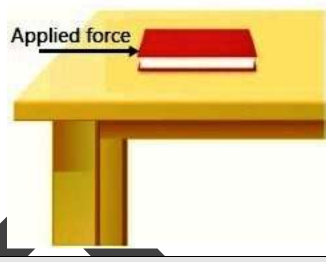
Unification of Weak Nuclear and Electromagnetic Forces: In 1979, Dr. Abdus Salam (a Pakistani scientist), along with Sheldon Glashow and Steven Weinberg, received the Nobel Prize in Physics for their work on the unification of the weak nuclear force and the electromagnetic force into a single framework called the **electroweak force**.

Although these two forces appear distinct in everyday life, the **electroweak theory** shows that they are two aspects of the same fundamental force, especially observable at very high energy levels.

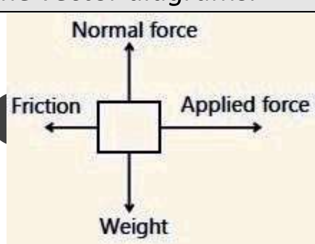
5. How can external forces on an object be represented using a free-body diagram?

External forces acting on an object may include $friction$, $gravity$, $normal\ force$, $drag$, $tension\ in\ a\ string$, or a $human\ force$ due to $pushing$ or $pulling$.

For example, when a book is pushed over the surface of a **tabletop** as shown in figure, we can represent the forces acting on it using a free-body diagram.



Free-body diagrams are used to show the relative magnitudes and directions of all the forces acting on an object in a given situation. In other words, a free-body diagram is a special example of the vector diagrams.



Usually, the **object** is represented by a **box**, and the force arrows are drawn outward from the centre of the box in the directions of the forces, as shown in figure. The length of a force arrow (line) reflects the magnitude of the force, and the arrowhead indicates the direction in which the force acts. Each force is labelled to indicate the exact type of force.

**** 6. What is Newton's First Law of Motion? Explain with examples.**

Newton's First Law of Motion states:

A body continues its state of rest or of uniform motion in a straight line unless acted upon by some external force.

It is our common observation that a force is required to move or stop a body. A **book placed on a table** remains there unless a force is applied to move it.

A ball rolling on the floor should continue to move with the same velocity in the absence of an applied force. However, in reality, the **ball stops** after covering some distance due to an opposing force (friction).

When a **fast-moving bus** stops suddenly, passengers bend forward as they try to continue moving. Conversely, when the bus starts moving quickly from rest, passengers are pushed back against the seat because they tend to stay at rest.

According to this law, a **bus** should continue moving without force, but due to friction between the tyres and the road, it eventually stops if the engine is turned off.

In **outer space**, if an object is thrown where no force acts on it, it would continue to move forever at a **constant velocity**.

The law also defines **force** as:

Force is an agency which changes or tends to change the state of rest or of uniform motion of a body.

In simple terms, force causes acceleration.

**** 7. An object moves with constant velocity in free space. How long will the object continue to move with this velocity?**

According to Newton's first law of motion, in outer space, if an object is thrown where no force acts on it, it would continue to move forever at a constant velocity.

**** 8. Why has not Newton's first law been proved on the Earth?**

According to newton's first law of motion, body should move with uniform velocity which is not possible on our Earth due to presence of some unbalanced force of friction. That's why everybody we throw stops after some time.

**** 9. When sitting in a car which suddenly accelerates from rest, you are pushed back into the seat, why?**

This is due to inertia, which resists changes in motion. When the car starts moving quickly from rest, passengers are pushed back against the seat because they tend to stay at rest.

***10. Define inertia and give an example.**

*The property of a body to maintain its state of rest or of uniform motion in a straight line is called **inertia**.*

As a result, Newton's First Law of Motion is sometimes called the **Law of Inertia** because it describes how objects resist changes in their state of motion unless acted upon by an **external force**.

For example, when a **tablecloth** is pulled abruptly from under dishes, the objects remain in their original positions due to **inertia**.

**** 11. Define Newton's Second Law of Motion and derive its mathematical form.**

If a net external force acts upon a body, it accelerates the body in the direction of force. The magnitude of acceleration is directly proportional to the magnitude of force and is inversely proportional to the mass of the body.

If a net force of magnitude F acts on a body of mass m and produces an acceleration of magnitude a, then the second law can be written mathematically as

$$a \propto F$$

$$and \qquad a \propto \frac{1}{m}$$

$$So \qquad a \propto \frac{F}{m}$$

$$or \qquad a = (constant)\frac{F}{m}$$

According to SI units, if $m = 1\ kg$, $a = 1ms^{-2}$, $F = 1\ N$, then the value of the constant will be 1. Therefore, the above equation can be written as:

$$a = (1)\frac{F}{m}$$

$$or \qquad F = ma$$

First law of motion provides the definition of force, i.e., a force produces an acceleration in a body. By the second law of motion ($F = ma$), we can calculate mathematically, the amount of force required to produce a certain amount of acceleration in a body of known mass. The SI unit of force is newton (N).

*One **newton** is the force which produces an acceleration of $1\ ms^{-2}$ in a body of mass $1\ kg$. From equation $F = ma$*

$$1N = 1\ kg \times 1\ ms^{-2}$$

**** 12. The force expressed in Newton's second law is a net force. Why is it so?**
Newton's second law $F = ma$ can only be expressed by net force because acceleration can only produce due to net force which acts upon the body.

13. What is the effect of force on velocity according to Newton's second law?
According to Newton's second law, a force can change the velocity of a body by producing acceleration or deceleration. Since **velocity** is a **vector quantity**, the change may occur in its **magnitude**, **direction**, or **both**.

**** 14. State Newton's Third Law of Motion with an example.**
Newton's Third Law of Motion states:

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

When two bodies interact, if body A exerts a force on body B (**action**), then body B exerts an equal and opposite force on body A (**reaction**).

For example, when we press a spring, the force applied by our hand on the spring is the **action**. The spring pushes back on our hand with an equal and opposite force, which is the **reaction**.

Since **action** and **reaction** forces act on **different bodies**, they **do not balance** each other. Thus, Newton's third law can also be expressed as follows:

"If one body exerts a force on a second body, the second body also exerts an equal and opposite force on the first body."

**** 15. An astronaut walking in space wants to return to his spaceship by firing a hand rocket. In what direction does he fire the rocket?**
The astronaut should fire the hand rocket in the opposite direction to the spaceship.

This is due to Newton's Third Law of Motion: *For every action, there is an equal and opposite reaction.* By firing the rocket backward, the reaction force will push the astronaut toward the spaceship.

16. Explain how forces act in pairs with examples, according to Newton's Third Law of Motion.
Forces always act in pairs during the interaction between two objects, following Newton's Third Law of Motion. These pairs are known as **action** and **reaction** forces. While we often notice one force causing an effect, the other force involved may go unnoticed. Here are some examples:

(i) Block on a Table: A block lying on a table experiences a downward force due to its **weight (w)**. The block exerts this force on the table. In response, the table applies an equal and opposite **normal reaction force (F_n)** upward on the block. These two forces balance each other, keeping the block at rest.

(ii) Bullet Fired from a Gun: When a bullet is fired, the **force of action (F)** propels the bullet forward. Simultaneously, the gun experiences a **reaction force (R)** in the opposite direction, causing it to **recoil**.

In both cases, action and reaction forces are **equal in magnitude**, **opposite in direction**, and act on **different bodies**, so they do not balance each other out.

***17. What are the limitations of Newton's Laws of Motion?**
Newton's laws of motion are highly accurate when applied to everyday objects and velocities. However, they have limitations in certain conditions:

(i) High Velocities: When dealing with objects moving at speeds close to the speed of light, Newton's laws fail to provide accurate results. In such cases, **relativistic mechanics** developed by **Albert Einstein** is used.

(ii) Elementary Particles: Newton's laws are not suitable for describing the motion of **elementary particles** at atomic or subatomic scales.

In conclusion, Newton's laws of motion are **not exact** for all types of motion but offer a **good approximation** for

M. Tayyab

most practical situations, except when an object is **very small** or moving **near the speed of light**.

18. What is difference between mass and weight?

Mass	*Weight*
Mass of a body is the quantity of matter in it. It determines the magnitude of acceleration produced when a force acts on it.	*The weight of an object is equal to the force with which the Earth attracts the body towards its centre.*
It is a **scalar quantity** (has magnitude only).	It is a **vector quantity** (has both magnitude and direction, directed towards the Earth's centre).
Mass remains **constant** everywhere.	Weight **varies** with the gravitational field strength (g) at different locations.
The SI unit of mass is **kilogram (kg)**.	The SI unit of weight is **newton (N)**.
Mass is measured using an **ordinary balance**.	Weight is measured using a **spring balance**.

19. What is a gravitational field? Explain gravitational field strength and how it affects the weight of an object.

*The **gravitational field** is the space around a mass where another mass experiences a force due to gravitational attraction.*

*The **gravitational field strength** is defined as the gravitational force acting on a unit mass.*

For a mass **m** on the surface of the Earth, the force it experiences (its **weight**) is given by:

$$w = mg$$

where g is the gravitational field strength, with a standard value of $10\ N\ kg^{-1}$.

Since the value of g varies depending on location and altitude, the weight of an object also changes accordingly. Though an object's weight may differ from place to place, at any specific location, its weight remains **proportional** to its mass. This allows for comparing the masses of two objects by comparing their weights at the same location.

- **Mass** is measured using an **ordinary balance**.
- **Weight** is measured using a **spring balance**.
- The **SI unit** of weight is **newton (N)**.

20. What is a mechanical balance? Explain its types.

A **mechanical balance** consists of a rigid horizontal beam that oscillates on a central knife edge acting as a fulcrum. It has two end knife edges equidistant from the centre. Two pans are suspended from the bearings on these knife edges (**Fig. a**).

Fig. a

The material to be weighed is placed in one pan, while standard weights are placed in the other. A pointer attached to the beam indicates the balance's deflection. The weights on the pan are adjusted until the beam reaches **equilibrium**.

Another type of mechanical balance is used for weighing **heavy items** such as flour bags, cement bags, and steel bars. These are known as **mechanical platform balances** (**Fig. b**). Unlike standard mechanical balances, they do not require additional standard weights. The **fulcrum** of the beam in such balances is positioned near one end, allowing much smaller weights to be placed at the other end to achieve equilibrium. These smaller weights are **pre-calibrated** to standard values.

Fig. b

21. How does an electronic balance work? How is it different from a mechanical balance?

An electronic balance does not require **standard weights** for measurement. It only needs to be connected to a **power supply**. Some models can also operate using **dry cell batteries**.

An electronic balance is **more precise** than a mechanical balance. When an object is placed on it, its mass is displayed on the screen. Modern electronic balances can even display the total price of a material if the **rate per kilogram** is fed into the balance.

22. What is a force meter, and how does it measure force?

A force meter is a scientific instrument used to measure force. It is also called a newton meter or a spring balance.

Digital force meters are now available for more precise measurements.

Unlike **mechanical and electronic balances**, which measure **mass** in kilograms, a force meter measures **force directly in newtons (N)**.

An ordinary force meter contains a spring with its upper end attached to a handle and a hook at the lower end to hold objects. A pointer is connected to the spring, which moves along a newton scale when an object is hung.

- In some force meters, the spring compresses under load, and the pointer indicates the weight.
- In others, the spring stretches, and the pointer is attached at the lower end.

M. Tayyab

M. Tayyab

Some **spring balances** provide mass readings, which can be **converted into newtons** by multiplying the mass (in kg) with g=10 ms^{-2}.

A **digital force meter** measures the **weight of an object directly in newtons**.

23. Why does a cricket ball stop moving after being hit by a bat?

When a cricket ball is hit, it moves with a high velocity. According to Newton's first law of motion, it should continue moving at a constant velocity. However, due to **friction between the ball and the ground**, the ball gradually slows down and stops. The force of friction acts opposite to the motion, causing energy dissipation in the form of heat.

24. What is friction, and what effect does it have on energy?

Friction is a **dissipative force** that opposes motion, causing energy to be wasted as work is done against it. The lost energy appears in the form of **heat**.

25. Give examples of energy dissipation due to friction in daily life and nature.

(i) **Rubbing Hands**: When we rub our hands together, heat is produced due to friction, making them **warm**.

(ii) **Machines Overheating**: The temperature of machines **rises** due to friction between moving parts, which can cause **damage**.

(iii) **Worn-out Tyres**: The tyres of vehicles wear out due to friction between the tyres and the road, especially when they **become too hot**.

(iv) **Shooting Stars:** The shooting stars seen in the night sky are actually asteroids entering Earth's atmosphere. Due to air resistance (friction), they experience a rise in temperature. Their temperature becomes so high that they **start burning** and ultimately disintegrate before reaching Earth.

**** 26. Describe the motion of a block on a table taking into account the friction between the two surfaces. What is the static friction and kinetic friction?**

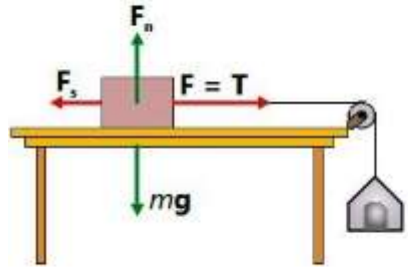
The friction between two solid surfaces is called sliding friction, which can be divided into two categories:

(i) Static Friction

(ii) Kinetic Friction

Explanation: When a block is placed on a table, it remains at rest due to the force of **static friction** acting between the two surfaces.

Static Friction: When an external force is applied to the block, static friction (F_s) opposes its motion, preventing it from moving. The block will not move until the applied force exceeds the maximum static friction. For example, when a weight is put in the pan of a force-measuring system, a force $F = T$ acts on the block, attempting to pull it. However, static friction resists the motion, keeping the block at rest as shown in the figure.



Kinetic Friction: If the applied force increases beyond the limit of static friction, the block begins to slide. At this point, kinetic friction comes into play. Kinetic friction is the force that opposes the motion of the block once it is already sliding. It is generally less than static friction and acts in the direction opposite to the motion of the block.

Thus, the motion of a block on a table is governed by static friction (which resists motion before sliding begins) and kinetic friction (which opposes motion after sliding starts).

27. Define terminal velocity of an object.

Terminal velocity is the constant velocity an object attains when the upward force of air resistance balances the downward force of gravity, causing the object to stop accelerating and continue falling at a steady speed.

28. How can you show that rolling friction is lesser than sliding friction?

The friction between two solid surfaces is called sliding friction, while rolling friction occurs when an object rolls over a surface.

A body with wheels faces less friction than a body without wheels. Similarly, ball bearings in machines reduce friction by allowing parts to roll instead of slide.

Rolling friction is about one hundred times smaller than sliding friction because the wheel touches the surface only at a point and does not slide.

29. What are the methods to reduce friction?

The following methods are used to reduce friction:

(i) The parts which slide against each other are highly polished.

(ii) Since the friction of liquids is less than that of solid surfaces, oil or grease is applied between the moving parts of the machinery.

(iii) As rolling friction is much less than the sliding friction, sliding friction is converted into rolling friction by the use of ball bearings in the machines and wheels under heavy objects.

(iv) High-speed vehicles, airplanes, and ships face friction from air or water. Their bodies are made streamlined (pointed front) to allow smooth airflow and reduce resistance.

**** 30. Define momentum and express Newton's second law of motion in terms of change in momentum.**

The momentum of a moving body is the product of its mass and velocity.

Mathematically,

$$p = m \times v$$

Momentum is a vector quantity, and its SI unit is $kgms^{-1}$ or Ns.

Newton's Second Law in Terms of Momentum:

According to Newton's second law of motion, the rate of change of momentum of a body is equal to the force acting on it.

When a ball is hit by a bat, a force F is exerted on the ball for a short interval of time $\triangle t$. In such cases, it is difficult to calculate the exact magnitude of the force, but the initial velocity v_i and final velocity v_f after collision can be determined. The acceleration a is given by:

$$a = \frac{\triangle v}{\triangle t}$$
$$a = \frac{v_f - v_i}{\triangle t}$$

From **Newton's second law**:

$$F = ma$$
$$F = m\left(\frac{v_f - v_i}{\triangle t}\right)$$
$$F \times \triangle t = m(v_f - v_i)$$
$$F \times \triangle t = mv_f - mv_i \qquad \because p = mv$$
$$F \times \triangle t = p_f - p_i$$
$$F \times \triangle t = \triangle p$$
$$F = \frac{\triangle p}{\triangle t}$$

This equation expresses Newton's second law in terms of momentum, stating that:

The rate of change of momentum of a body is equal to the force acting on it, and the direction of change in momentum is the same as the direction of the applied force.

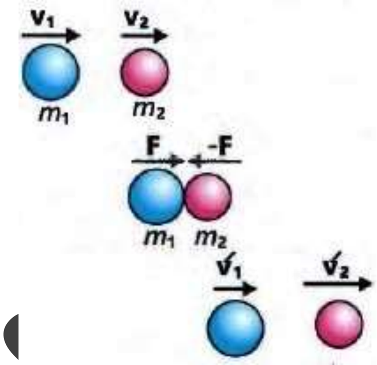
**** 31. Define impulse of force.**

When a large force F acts on an object for a short time $\triangle t$, the product $F \times \triangle t$ is called **Impulse**, which is equal to the total change in momentum of the object.

$$Impulse = F \times \triangle t$$
$$Impulse = \frac{\triangle p}{\triangle t} \times \triangle t$$
$$Impulse = \triangle p$$
$$Impulse = \text{ change in momentum}$$

**** 32. State and explain the principle of conservation of momentum.**

If no external force acts on an isolated system, the final total momentum of the system is equal to the initial total momentum of the system.



The collection of objects is known as a **system**.

If no external force acts on any object of the system, it is known as an **isolated system**.

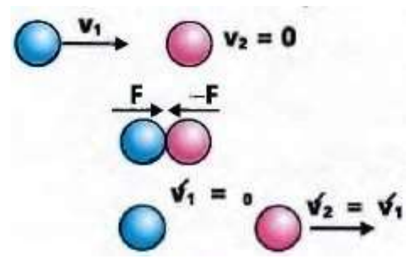
Explanation: Consider a system of two balls of masses m_1 and m_2. Suppose that the balls are moving with velocities v_1 and v_2 along a straight line in the same direction. If $v_1 > v_2$, the balls will collide as shown in figure. If their velocities become v_1' and v_2' respectively after collision, then:

$$Total\ momentum\ of\ the\ system\ before\ collision = m_1v_1 + m_2v_2$$
$$Total\ momentum\ of\ the\ system\ after\ collision = m_1v_1' + m_2v_2'$$

Thus, according to the principle of conservation of momentum:

$$\begin{matrix} Total\ momentum\ of\ the \\ system\ before\ collision \end{matrix} = \begin{matrix} Total\ momentum\ of\ the \\ system\ after\ collision \end{matrix}$$
$$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$$

To explain this principle, let us consider the **collision of two identical balls** in which the second ball is at rest.



When there is a collision of two balls, there is a transfer of momentum from one ball to another. The ball at rest gains momentum and starts moving whereas the striking ball slows down. If the balls are identical, we will observe that there is a total transfer of momentum. The striking ball comes to rest and the other ball starts moving with the same speed as shown in figure.

This means that the second ball gains momentum equal to that lost by the first one. If the first ball stops after collision, the second ball moves with the momentum of the first ball. This suggests that the total momentum of the two balls after collision remains the same as the total momentum before collision.

The principle of conservation of momentum is applicable not only to macro-objects but also for micro-objects like atoms and molecules.

Important Formulas

- **Newtons Second Law** $F = ma$
- **Formula of Weight** $w = mg$
- **Relation Between Force and Momentum** $F = \frac{\Delta P}{T}$
- **Centripetal Force** $F_c = \frac{mv^2}{r}$
- **Frictional Force** $F_s = \mu mg$
- **Relation Between Force and Momentum**

$$F = \frac{\triangle p}{\triangle t}$$

- **Impulse**

$$Impulse = F \times \triangle t$$
$$Impulse = \frac{\triangle p}{\triangle t} \times \triangle t$$
$$Impulse = \triangle p$$
$$Impulse = Change\ in\ momentum$$

3.1. A $10\ kg$ block is placed on a smooth horizontal surface. A horizontal force of $5\ N$ is applied to the block. Find:

(a) the acceleration produced in the block.

(b) the velocity of block after $5\ seconds$.

Given Data

$$Mass\ of\ block = m = 10\ kg$$
$$Force = F = 5\ N$$
$$Initial\ velocity = v_i = 0\ ms^{-1}$$

To Find

$$Acceleration = a = ?$$
$$Final\ velocity = v_f = ?$$

Solution

According to second law of motion

$$F = ma$$
$$5 = (10)\ (a)$$
$$\frac{5}{10} = a$$
$$0.5 = a$$
$$\boldsymbol{a = 0.5\ ms^{-2}}$$

Now by using first equation of motion

$$v_f = v_i + at$$
$$v_f = 0 + (0.5)(5)$$
$$v_f = 0 + 2.5$$
$$\boldsymbol{v_f = 2.5\ ms^{-1}}$$

3.2. The mass of a person is $80\ kg$. What will be his weight on the Earth? What will be his weight on the Moon? The value of acceleration due to gravity of Moon is $1.6\ ms^{-2}$.

Given Data

$$Mass\ of\ body = m = 80\ kg$$
$$Value\ of\ g\ on\ the\ surface\ of\ Earth = g_E = 10\ ms^{-2}$$
$$Value\ of\ g\ on\ the\ surface\ of\ Moon = g_M = 1.6\ ms^{-2}$$

To Find

$$Weight\ on\ the\ surface\ of\ Earth = w_E = ?$$
$$Weight\ on\ the\ surface\ of\ Moon = w_M = ?$$

Solution

By using formula of weight $w = mg$

$$w_E = mg_E$$
$$w_E = (80)(10)$$
$$\boldsymbol{w_E = 800\ N}$$

Now again by using formula of weight $w = mg$

$$w_M = mg_M$$
$$w_M = (80)(1.6)$$
$$\boldsymbol{w_M = 128\ N}$$

3.3. What force is required to increase the velocity of $800\ kg$ car from $10\ ms^{-1}$ to $30\ ms^{-1}$ in $10\ seconds$?

Given Data

$$Mass\ of\ car = m = 800\ kg$$
$$Initial\ velocity = v_i = 10\ ms^{-1}$$
$$Final\ velocity = v_f = 30\ ms^{-1}$$
$$Time = t = 10\ s$$

To Find

$$Force = F = ?$$

Solution

According to second law of motion

$$F = ma$$
$$F = (m)\left(\frac{v_f - v_i}{t}\right)$$
$$F = (800)\left(\frac{30 - 10}{10}\right)$$
$$F = (800)\left(\frac{20}{10}\right)$$
$$F = (800)(2)$$
$$\boldsymbol{F = 1600\ N}$$

3.4. A $5\ g$ bullet is fired by a gun. The bullet moves with a velocity of $300\ ms^{-1}$. If the mass of the gun is $10\ kg$, find the recoil speed of the gun.

M. Tayyab

Given Data

$$\begin{aligned}&Mass\ of\ bullet = m = 5\ g\\&m = \frac{5}{1000}\ kg\\&m = 0.005\ kg\\&Velocity\ of\ bullet = v = 300\ ms^{-1}\\&Mass\ of\ gun = M = 10\ kg\end{aligned}$$

To Find

$$Recoil\ speed\ of\ the\ gun = V = ?$$

Solution

According to law of conservation of momentum

$$\begin{aligned}&\begin{matrix}Total\ momentum\\ before\ firing\end{matrix} = \begin{matrix}Total\ momentum\\ after\ firing\end{matrix}\\&0 = MV + mv\\&0 = (10)V + (0.005)(300)\\&0 = 10V + 1.5\\&-1.5 = 10V\\&\frac{-1.5}{10} = V\\&-0.15 = V\\&\boldsymbol{V = -0.15\ ms^{-1}}\end{aligned}$$

Negative sign indicates the gun recoils. $i.e$ move in backward direction opposite to the motion of bullet.

3.5. An astronaut weighs $70\ kg$. He throws a wrench of mass $300\ g$ at a speed of $3.5\ ms^{-1}$. Determine:

(a) the speed of astronaut as he recoils away from the wrench.

(b) the distance covered by the astronaut in 30 minutes.

Given Data

$$\begin{aligned}&Mass\ of\ astronaut = M = 70\ kg\\&Mass\ of\ wrench = m = 300\ g\\&m = \frac{300}{1000}\ kg\\&m = 0.3\ kg\\&Speed\ of\ wrench = v = 3.5\ ms^{-1}\\&Time = t = 30\ min.\\&t = 30 \times 60\ s\\&t = 1800\ s\end{aligned}$$

To Find

$$\begin{aligned}&Recoil\ speed\ of\ the\ astronaut = V = ?\\&Distance\ covered\ in\ 30\ minutes = S = ?\end{aligned}$$

Solution

According to law of conservation of momentum

$$\begin{aligned}&\begin{matrix}Total\ momentum\\ before\ throwing\end{matrix} = \begin{matrix}Total\ momentum\\ after\ throwing\end{matrix}\\&0 = MV + mv\\&0 = (70)V + (0.3)(3.5)\\&0 = 10V + 1.05\\&-1.05 = 70V\\&\frac{-1.05}{70} = V\\&-0.015 = V\\&V = -0.015\ ms^{-1}\\&\boldsymbol{V = -1.5 \times 10^{-2} ms^{-1}}\end{aligned}$$

Negative sign indicates the astronaut recoils (moves in the opposite direction of the wrench).

Now by using formula of distance

$$\begin{aligned}&S = Vt\\&S = (0.015)(1800)\\&\boldsymbol{S = 27\ m}\end{aligned}$$

We don't take negative speed for distance because: Distance is always positive. The negative sign shows direction, not how far something moves.

3.6. A $6.5 \times 10^3\ kg$ bogie of a goods train is moving with a velocity of $0.8\ ms^{-1}$. Another bogie of mass $9.2 \times 10^3\ kg$ coming from behind with a velocity of $1.2\ ms^{-1}$ collides with the first one and couples to it. Find the common velocity of the two bogies after they become coupled.

Given Data

$$\begin{aligned}&Mass\ of\ first\ bogie = m_1 = 6.5 \times 10^3\ kg\\&Velocity\ of\ first\ bogie = v_1 = 0.8\ ms^{-1}\\&Mass\ of\ second\ bogie = m_2 = 9.2 \times 10^3\ kg\\&Velocity\ of\ second\ bogie = v_2 = 1.2\ ms^{-1}\end{aligned}$$

To Find

$$Common\ velocity\ after\ coupling\ = V\ = ?$$

Solution

According to law of conservation of momentum

$$\begin{aligned}&\begin{matrix}Total\ momentum\\ before\ couple\end{matrix} = \begin{matrix}Total\ momentum\\ after\ couple\end{matrix}\\&m_1v_1 + m_2v_2 = m_1V + m_2V\\&m_1v_1 + m_2v_2 = V(m_1 + m_2)\\&(6.5 \times 10^3)(0.8) + (9.2 \times 10^3)(1.2)\\&\qquad = V[(6.5 \times 10^3) + (9.2 \times 10^3)]\\&5200 + 11040 = V(15700)\\&\frac{16240}{15700} = V\\&1.03 = V\\&\boldsymbol{V = 1.03\ ms^{-1}}\end{aligned}$$

3.7. A cyclist weighing $55\ kg$ rides a bicycle of mass $5\ kg$. He starts from rest and applies a force of $90\ N$ for $8\ seconds$. Then he continues at a constant speed for another $8\ seconds$. Calculate the total distance travelled by the cyclist.

Given Data

M. Tayyab

$Mass\ of\ cyclist = m_1 = 55\ kg$
$Mass\ of\ bicycle = m_2 = 5\ kg$
$Total\ mass\ = m\ = 55\ kg\ +\ 5\ kg$
$m\ =\ 60\ kg$
$Force\ applied\ =\ F = 90\ N$
$Time\ of\ acceleration\ =\ t_1\ =\ 8\ s$
$Time\ of\ constant\ speed\ =\ t_2 =\ 8\ s$
$Initial\ speed = v_i = 0\ ms^{-1}$

To Find

$$Total\ distance\ travelled\ = S = ?$$

Solution

According to second law of motion

$$F = ma$$
$$90 = (60)\ (a)$$
$$\frac{90}{60} = a$$
$$1.5 = a$$
$$a = 1.5\ ms^{-2}$$

Now by using first equation of motion

$$v_f = v_i + at_1$$
$$v_f = 0 + (1.5)(8)$$
$$v_f = 0 + 12$$
$$v_f = 12\ ms^{-1}$$

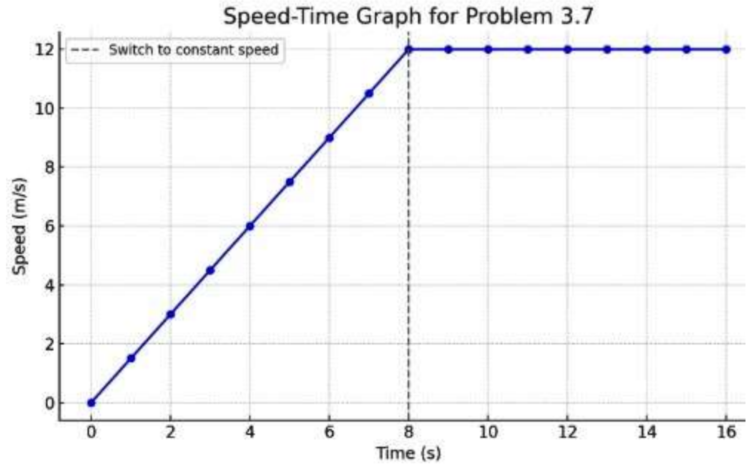
Distance covered **during acceleration** by using second equation of motion

$$S_1 = v_i t_1 + \frac{1}{2} a {t_1}^2$$
$$S_1 = (0)(8) + \frac{1}{2}(1.5)(8)^2$$
$$S_1 = 0 + \frac{1}{2}(1.5)(64)$$
$$S_1 = 0 + 48$$
$$S_1 = 48\ m$$

Distance covered at **constant speed** by formula $S = vt$

$$S_2 = v_f t_2$$
$$S_2 = (12)(8)$$
$$S_2 = 96\ m$$

$Total\ distance\ travelled\ = S = S_1 + S_2$
$S = 48\ m + 96\ m$
$\boldsymbol{S = 144\ m}$



3.8. A ball of mass $0.4\ kg$ is dropped on the floor from a height of $1.8\ m$. The ball rebounds straight upward to a height of $0.8\ m$. What is the magnitude and direction of the impulse applied to the ball by the floor?

Given Data

$Mass\ of\ ball = m = 0.4\ kg$
$Drop\ height = h_1 = 1.8\ m$
$Rebound\ height = h_2 = 0.8\ m$
$Acceleration\ due\ to\ gravity = g = 10\ ms^{-2}$

To Find

$$Impulse\ (magnitude\ and\ direction) = ?$$

Solution

Since the ball is dropped so, $v_i = 0\ ms^{-1}$

$$2gh_1 = v_f^2 - v_i^2$$
$$2(10)(1.8) = v_f^2 - (0)^2$$
$$36 = v_f^2$$
$$v_f^2 = 36$$
$$\sqrt{v_f^2} = \sqrt{36}$$
$$v_f = \pm 6\ ms^{-1}$$

But since the ball is moving downward, we select the negative root. $i.e$

$$v_f = v_{before} = -6\ ms^{-1}$$

At maximum rebound height, $v_f = 0\ ms^{-1}$

$$2gh_2 = v_f^2 - v_i^2$$
$$2(-10)(0.8) = (0)^2 - v_i^2\ \ (\because ball\ moving\ upward)$$
$$-16 = -v_i^2$$
$$v_i^2 = 16$$
$$\sqrt{v_i^2} = \sqrt{16}$$
$$v_i = \pm 4\ ms^{-1}$$

But since the ball is moving upward, we select the positive root. $i.e$

$$v_i = v_{after} = 4\ ms^{-1}$$

M. Tayyab

Now by using formula of impulse

$$
\begin{aligned}
&Impulse = Change\ in\ momentum\\
&= \triangle p\\
&= p_f - p_i\\
&= mv_f - mv_i\\
&= m(v_f - v_i)\\
&= m(v_{after} - v_{befor})\\
&= (0.4)[4-(-6)]\\
&= (0.4)[10]\\
&\boldsymbol{Impulse = 4\ Ns}
\end{aligned}
$$

The **positive result** means the impulse is **upward** (floor pushes the ball up).

Note: In physics, we always choose a reference direction to be positive.

For vertical motion:

- We choose upward as positive (by convention).
- So, any velocity in the upward direction is positive.
- And any velocity in the downward direction is negative.

3.9. Two balls of masses $\mathbf{0.2}\ \boldsymbol{kg}$ and $\mathbf{0.4}\ \boldsymbol{kg}$ are moving towards each other with velocities $\mathbf{20}\ \boldsymbol{ms^{-1}}$ and $\mathbf{5}\ \boldsymbol{ms^{-1}}$ respectively. After collision, the velocity of $\mathbf{0.2}\ \boldsymbol{kg}$ ball becomes $\mathbf{6}\ \boldsymbol{ms^{-1}}$. What will be the velocity of $\mathbf{0.4}\ \boldsymbol{kg}$ ball?

Given Data

$$
\begin{aligned}
&Mass\ of\ ball\ A = m_1 = 0.2\ kg\\
&Mass\ of\ ball\ B = m_2 = 0.4\ kg\\
&Initial\ velocity\ \ of\ ball\ A = v_1 = 20\ ms^{-1}\\
&Initial\ velocity\ \ of\ ball\ B = v_2\\
&\qquad\qquad = -5\ ms^{-1}(opposite\ direction)\\
&Final\ velocity\ of\ ball\ A = v_1' = 6\ ms^{-1}
\end{aligned}
$$

To Find

$$Final\ velocity\ of\ ball\ B =\ v_2' = ?$$

Solution

According to law of conservation of momentum

$$
\begin{aligned}
&\begin{matrix} total\ momentum\ of\ the \\ system\ before\ collision \end{matrix} = \begin{matrix} total\ momentum\ of\ the \\ system\ after\ collision \end{matrix}\\
&m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'\\
&(0.2)(20) + (0.4)(-5) = (0.2)(6) + (0.4)(v_2')\\
&4 - 2 = 1.2 + (0.4)(v_2')\\
&2 - 1.2 = 0.4v_2'\\
&0.8 = 0.4v_2'\\
&\frac{0.8}{0.4} = v_2'\\
&2 = v_2'\\
&\boldsymbol{v_2' = 2\ ms^{-1}}
\end{aligned}
$$

M. Tayyab