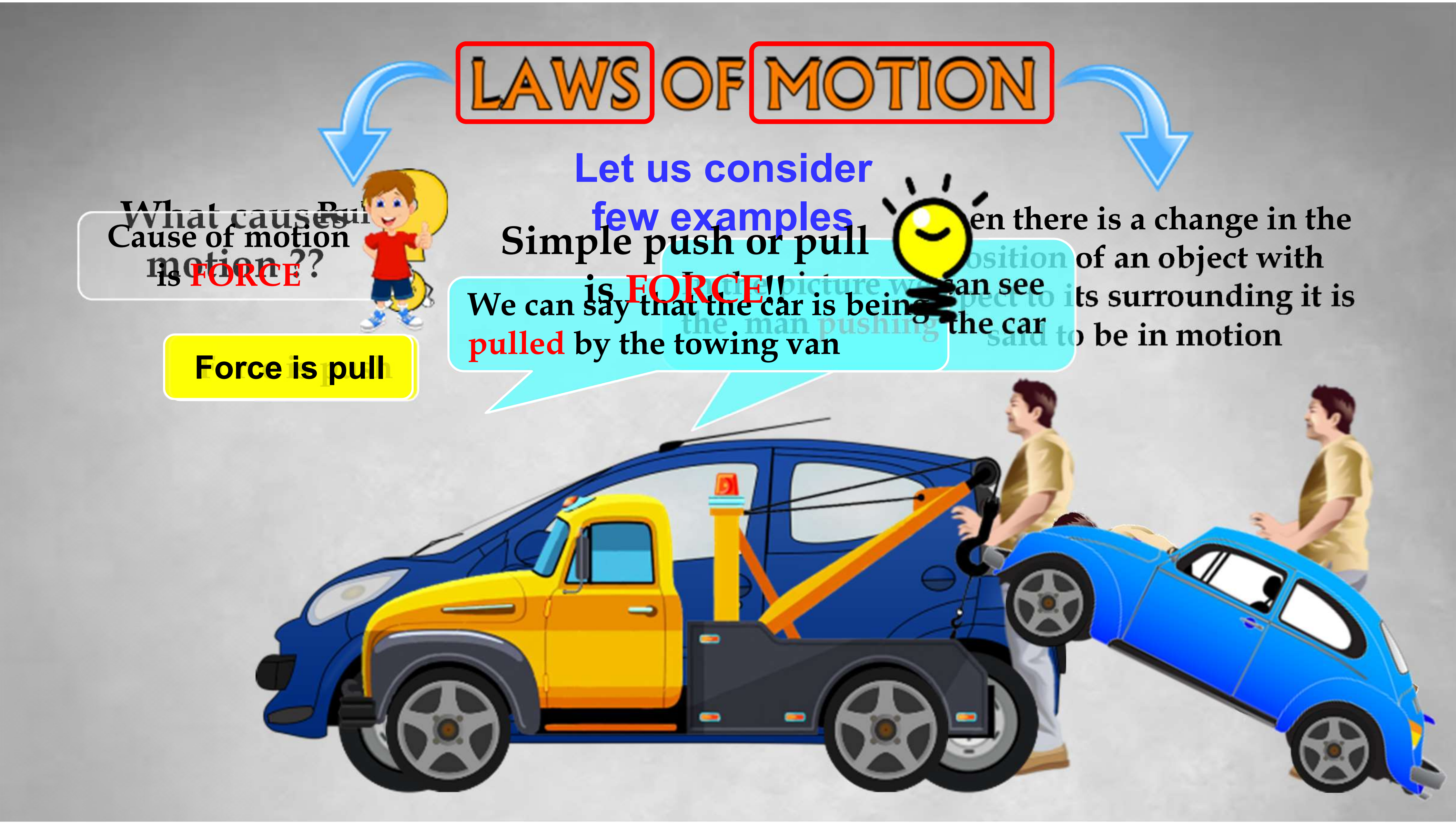
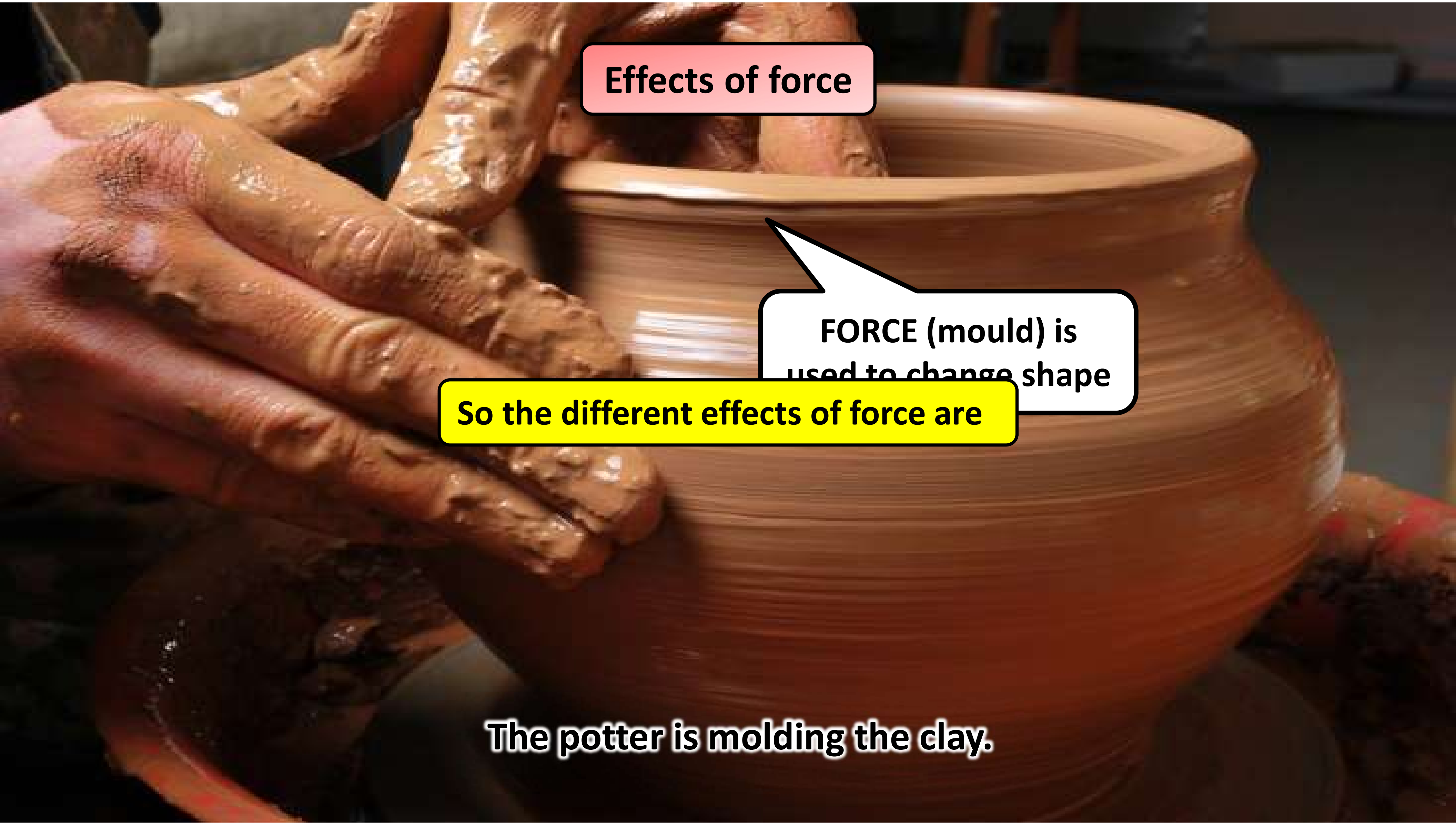
LAWS OF MOTION

- **Cause of motion**
- **Balanced and Unbalanced forces**



LAWS OF MOTION
Let us consider few examples
Cause of motion is FORCE
Simple push or pull is FORCE!!
We can say that the car is being pulled by the towing van
Force is pull
en there is a change in the
of an object with
its surrounding it is
be in motion
an see
the car


Effects of force
FORCE (mould) is
used to change shape
So the different effects of force are
The potter is molding the clay.

FORCE

BALANCED FORCE

Are there different kinds of Forces?

Yes….!

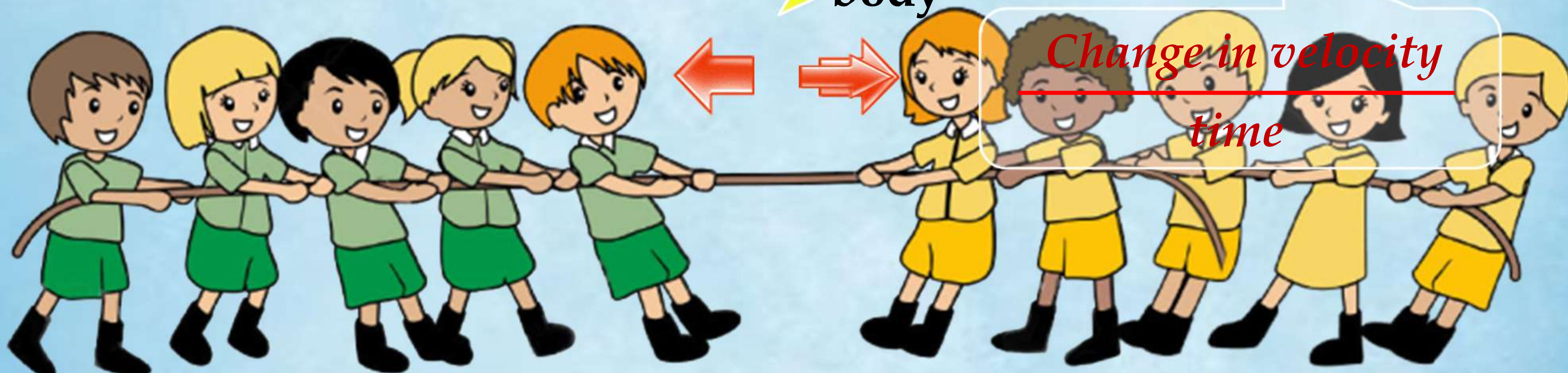
1. Forces which are equal in magnitude and opposite in direction acting on the same body
2. They do not change the state of rest or of uniform motion

UNBALANCED FORCE

1. Forces which are unequal in magnitude and acting on the same body
2. Changes the state of rest or of motion. Causes acceleration in a body

Both teams exert equal forces on the rope in opposite direction.

Hence, both forces balance each other

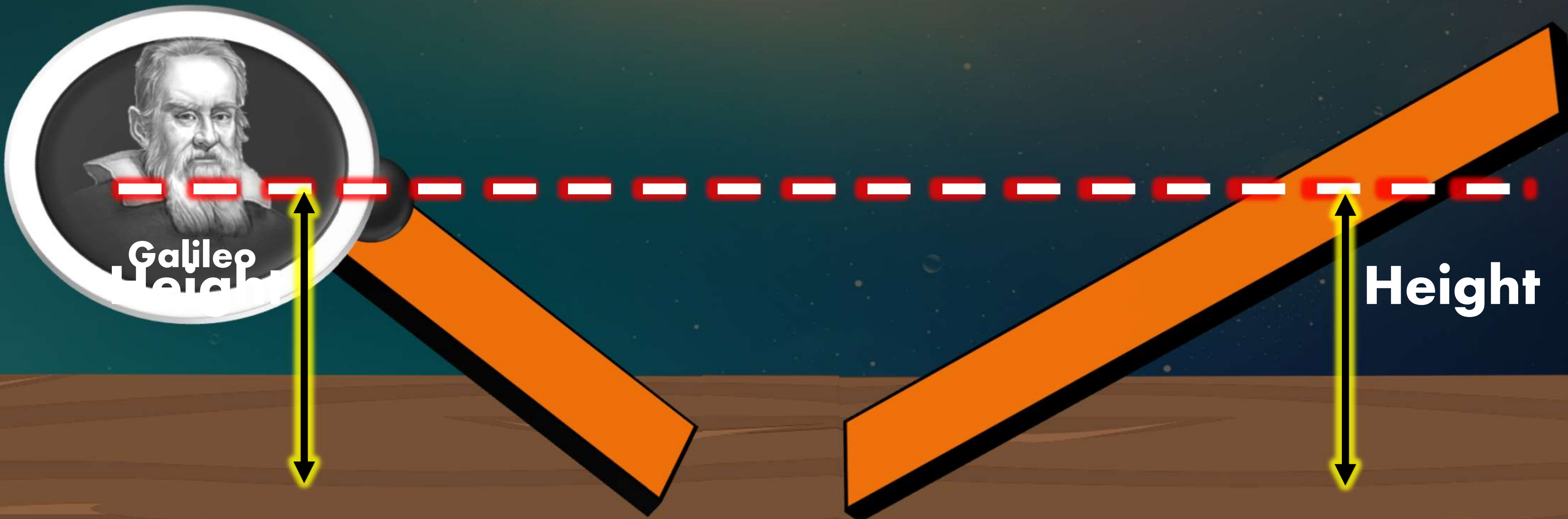


Change in velocity
time

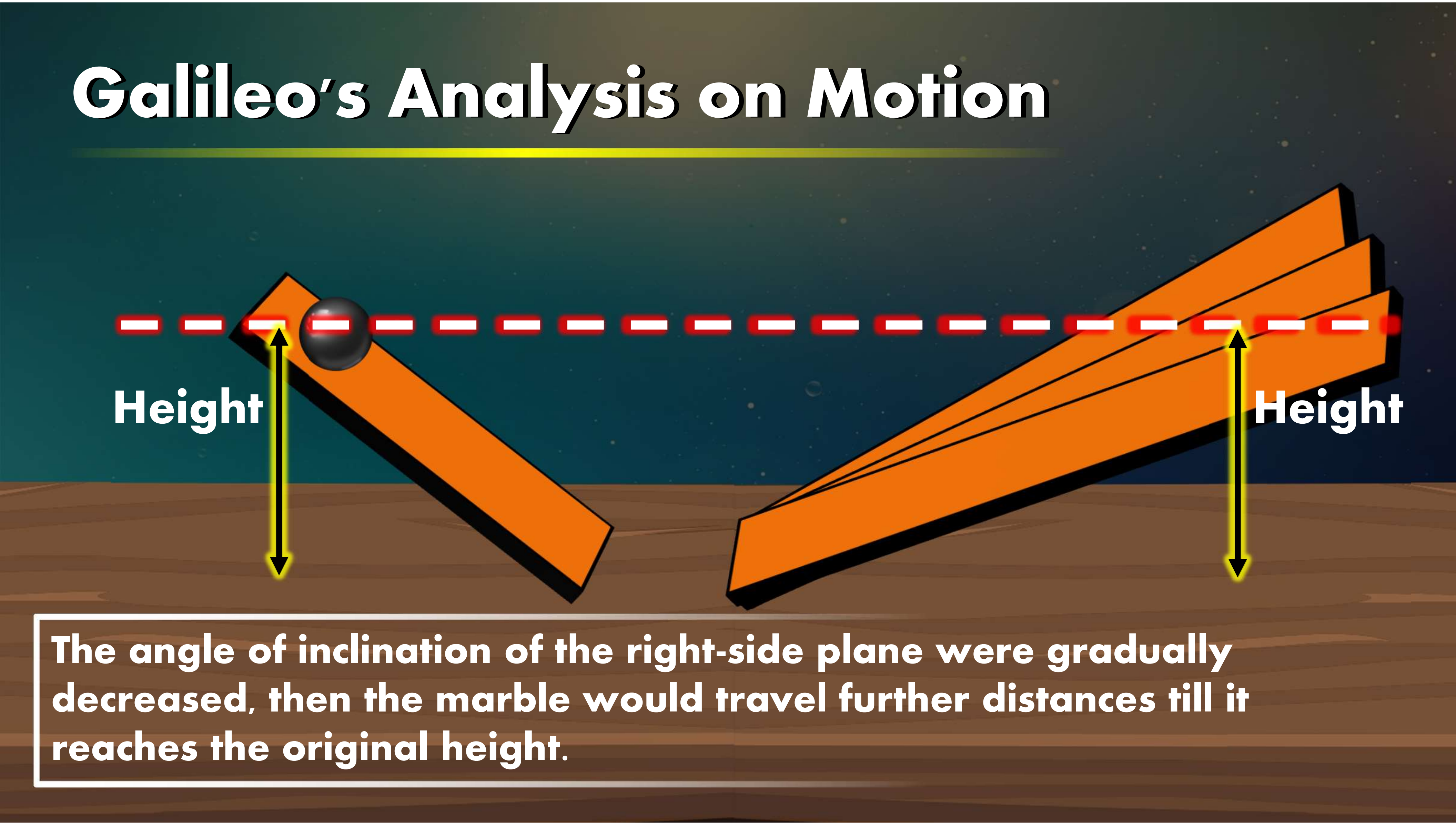
LAWS OF MOTION

- Galileo's Analysis on Motion
- Inertia
- Newton’s 1st Law of motion

Galileo's Analysis on Motion



When the marble is released from left, it would roll down the slope and go up on the opposite side to the same height from which it was released.


Galileo's Analysis on Motion
Height
Height
The angle of inclination of the right-side plane were gradually decreased, then the marble would travel further distances till it reaches the original height.

Galileo's Analysis on Motion

Galileo deduced that objects move with a constant speed when no force acts on them.

If the right-side plane were ultimately made horizontal, the marble would continue to travel forever trying to reach the same height that it was released from. The unbalanced forces on the marble in this case are zero

Newton’s Laws of Motion

Newton studied ideas on force and motion and presented three Fundamental Laws.

Sir Isaac Newton

These Laws are known as…..

Newton’s Laws of Motion

INERTIA

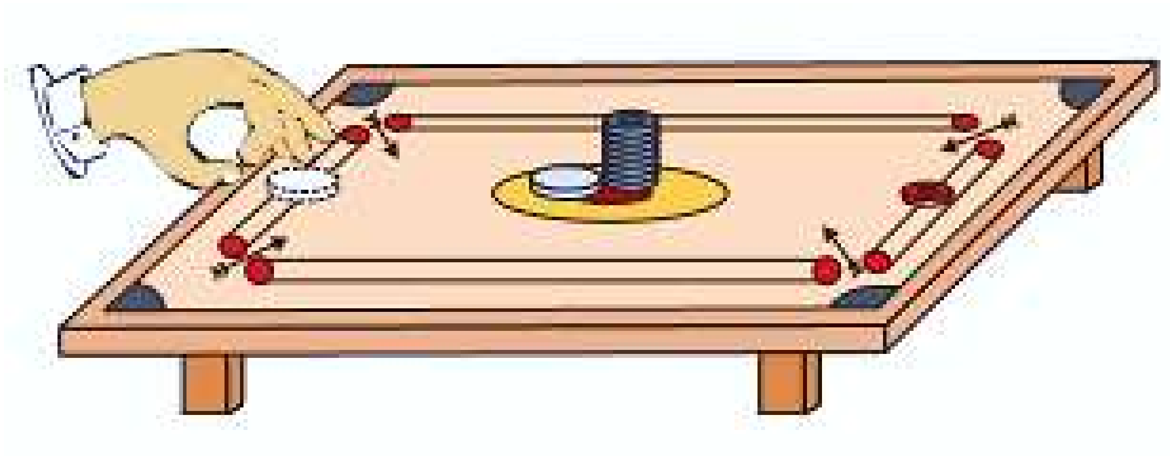
Inertia is the tendency of a body to resist change in its state of rest or state of motion.

Means to **resist**

Body at rest remains at rest

Body in motion remains in motion

EXAMPLES OF INERTIA



Newton’s first law of motion

Newton’s first law of motion is stated as:

An object r… t or of uniform motion in a straight line unless com… orce.

The person kicks (unbalanced force) forces to change the state from rest to motion.

… is at rest and will … to be at rest.

This law can be said in another way

All objects resist a change in their state of motion

“The Law Of Inertia”

Is nothing but inertia.

Name the property of bodies to resist a change in their velocities.

Ans : Inertia

Which of the following has more inertia: (a) a rubber ball and a stone of the same size? (b) a bicycle and a train (c) a five rupee coin and a one-rupee coin?

Ans : (a) Stone
(b) Train and
(c) A five rupee coin

Heavier or more massive objects offer larger inertia.

Quantitatively, the inertia of an object is measured by its mass.

In the following example, try to identify the number of times the velocity of the ball changes:

"A football player kicks a football to another player of his team who kicks the football towards the goal. The goalkeeper of the opposite team collects the football and kicks it towards a player of his own team".

Also identify the agent supplying the force in each case.

Ans : The velocity of ball changes three times.

First time, the velocity changes when the FOOTBALL PLAYER of one team kicks the ball.

Second time, the velocity changes when ANOTHER PLAYER OF SAME TEAM kicks the football.

Third time, the velocity changes when the GOALKEEPER of the opposite team kicks the football.

Explain why some of the leaves may get detached from a tree if we vigorously shake its branch.

Ans : Before shaking the branches, leaves are at rest. When branches are shaken, they come in motion while the leaves tend to remain at rest due to inertia of rest. As a result leaves get detached from the branches and fall down.

Why do you fall in the forward direction when a moving bus brakes to a stop and fall backwards when it accelerates from rest?

Or

(i) Why do the passengers in a bus tend to fall forward when it suddenly stops?

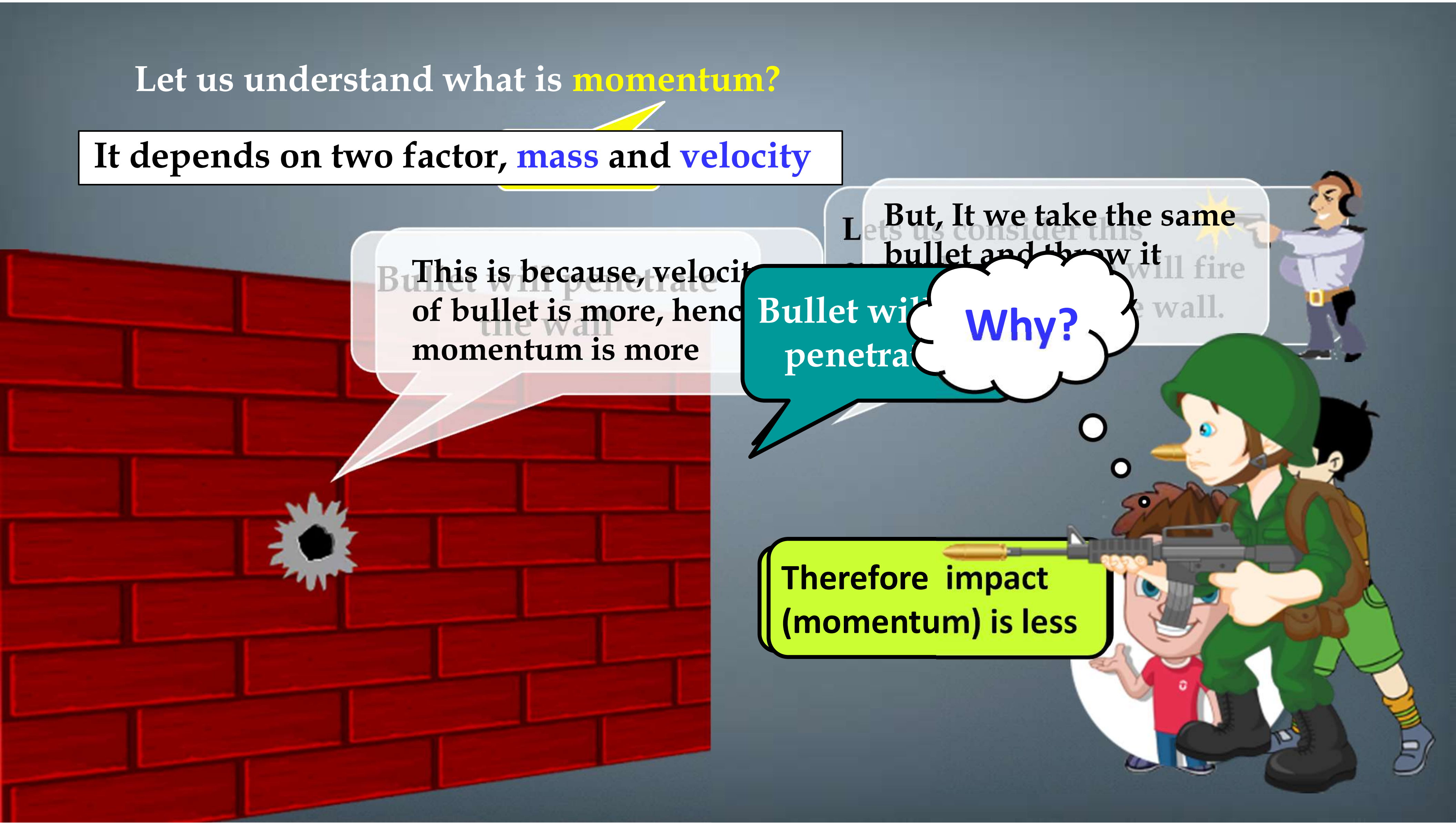
(ii) Why do the passengers in a bus tend to fall backward when it starts suddenly?

Ans : (i) When a moving bus stops, the lower part of our body in contact with the bus comes to rest while the upper part of our body tends to keep moving due to inertia of motion. Hence, we fall downwards (or forwards).

(ii) When the bus accelerates from rest, the lower part of our body comes into motion along with the bus while the upper part of body teds to remain at rest due to inertia of rest. Hence we fall backwards.

LAWS OF MOTION

- Momentum
- Units


Let us understand what is momentum?
It depends on two factor, mass and velocity
This is because, velocit
of bullet is more, henc
momentum is more
But, It we take the same
bullet and throw it
Why?
Therefore impact
(momentum) is less

Let us consider another example !

MOMENTUM (P)

Momentum (P) of an object is defined as product of its mass and velocity

Momentum = mass $\times$ velocity

$$P = m \times v$$

$$P = mv$$

Momentum is a **vector** quantity

Needs both magnitude and direction

UNIT

$$P = m \times v$$

SI / MKS	P =	kg	m/s
CGS	P =	g	cm/s

Q. It is easy to stop a tennis ball than a cricket ball moving with the same velocity.

Sol :

Tennis ball

Cricket ball

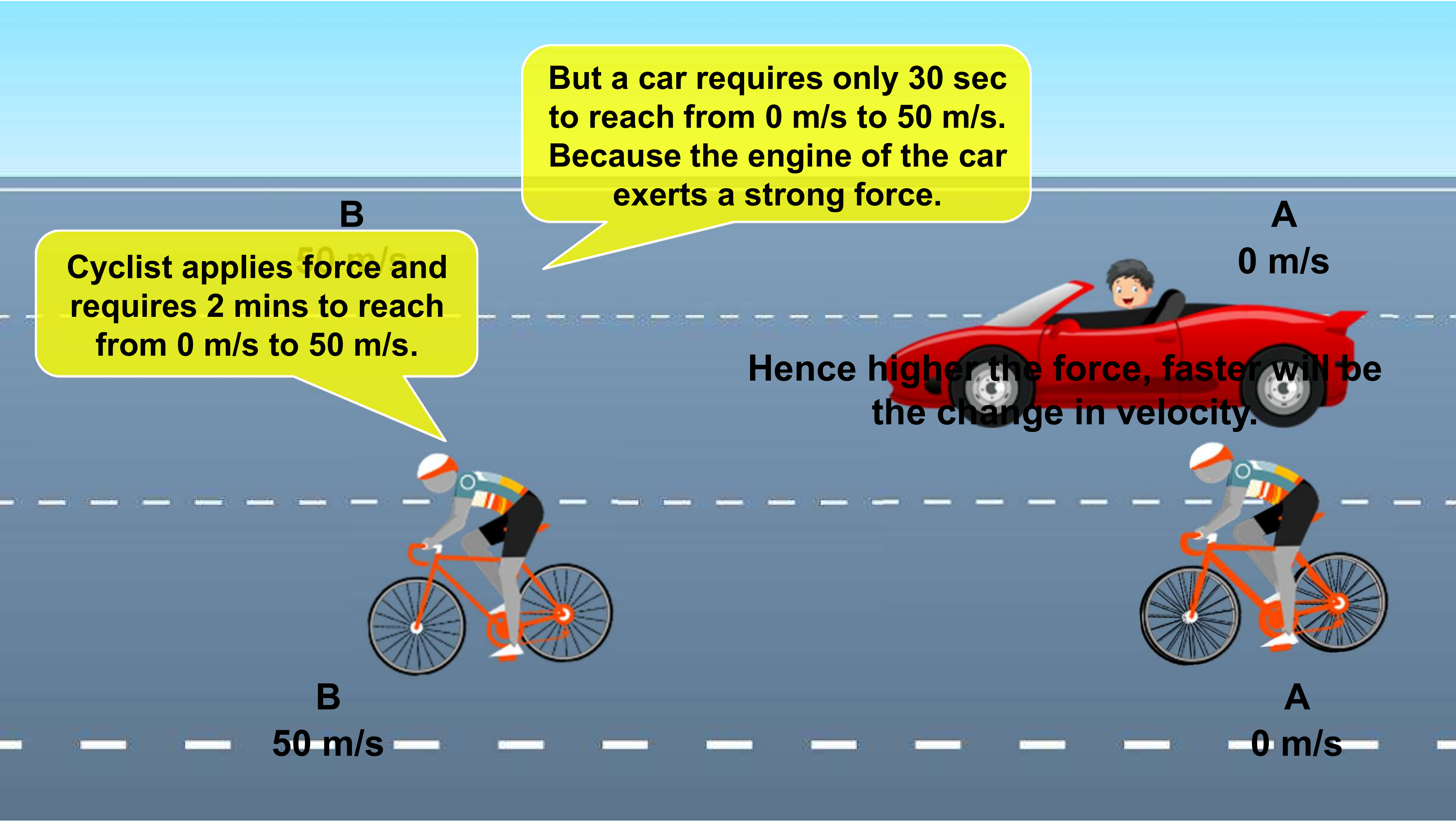
Mass is less hence momentum is less

Mass is more hence momentum is more

1. Momentum of an object depends on its mass as well as its velocity.
2. Cricket ball is more heavy than a tennis ball. Although they are thrown with the same velocity, cricket ball has more momentum than a tennis ball.
3. Hence, more force is required to stop a cricket ball than a tennis ball.
4. Hence, it is easier to stop a tennis ball than a cricket ball moving with same velocity.

LAWS OF MOTION

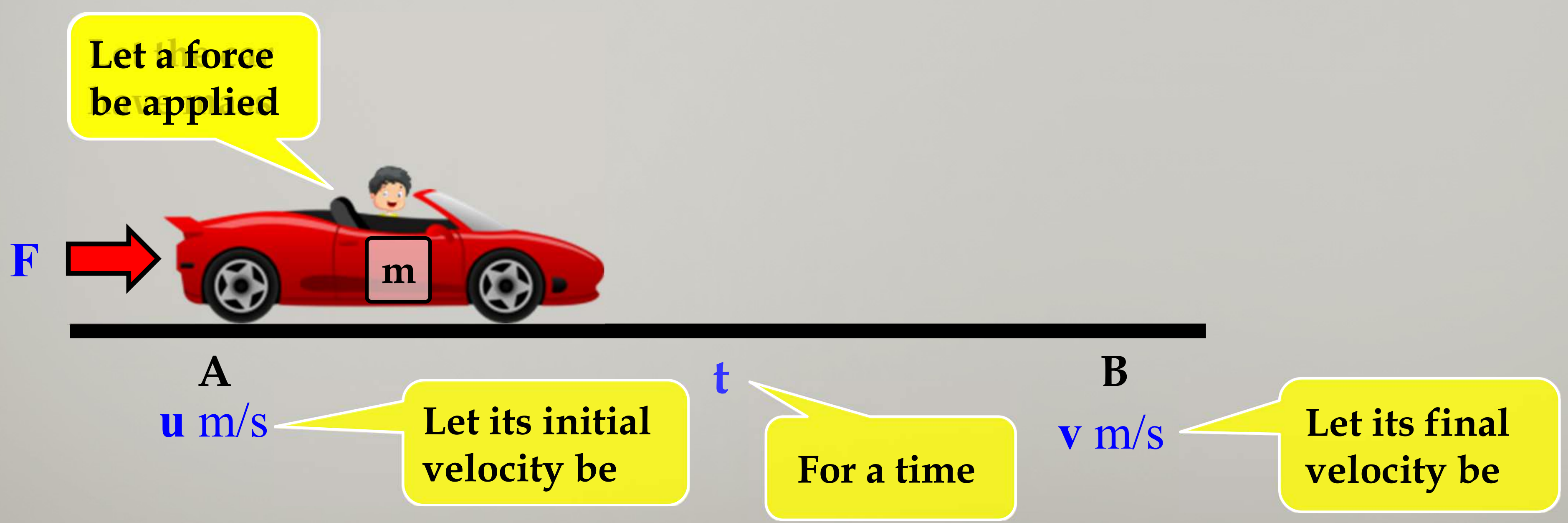
- Newton's 2^{nd} Law of motion
- Mathematical formulation


But a car requires only 30 sec to reach from 0 m/s to 50 m/s. Because the engine of the car exerts a strong force.
B
A
0 m/s
Cyclist applies force and requires 2 mins to reach from 0 m/s to 50 m/s.
Hence higher the force, faster will be the change in velocity.
B
50 m/s
A
0 m/s

NEWTON’S SECOND LAW OF MOTION

Newton’s second law of motion states that:

The second law of motion states that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force.



Math
Se

momentum of the object will be, $p_1 = mu$ and $p_2 = mv$ respectively.

The change in momentum $\propto p_2 - p_1$
$\propto mv - mu$
$\propto m \times (v - u)$.

The rate of change of momentum $\propto \dfrac{m \times (v-u)}{t}$

Or, the applied force,

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

$$F = \frac{km \times (v-u)}{t} \quad (9.2)$$

$$= kma \quad (9.3)$$

to second law

P_1 = mu P_2 =

Momentum = mass × velocity

Rate of Change of momentum =

Let P_1 be the initial momentum.

Cha

Let

momentum.

With respect to time

= m

Final – initial

F

= m × (v-u) / t

∴ a = (v-u) / t

A B

t

u m/s

u m/s

Rate of Change of momentum = ma

nge Applied

nge of momentum ∝ force

proportional to the

leration

Applied force F

OR rate of change of velocity.

F ∝ ma

F = kma

If k = 1,

'k' is the proportionality constant.

Then F = ma

LAWS OF MOTION

- Force
- Units
- Distinguish between force and momentum

Force is a VECTOR quantity

Force Equation

m is Mass

a is acceleration

$F = ma$

Needs both magnitude and direction

$kg\,m/s^2$

$g\,cm/s^2$

units

SI/MKS	CGS
newton (N)	dyne

Let us define 1 newton & 1 dyne

$$F = ma$$

1 newton = 1kg × 1 m/s^2

1 newton = The force necessary to cause an acceleration of 1 m/s^2 in an object of mass 1 kg is called 1 newton.

1 dyne = 1g × 1 cm/s^2

1 dyne = The force necessary to cause an acceleration of 1 cm/s^2 in an object of mass 1 gm is called 1 dyne.

A truck of mass m is moved under a force F. If the truck is then loaded with an object equal to the mass of the truck and the driving force is halved, then how does an acceleration change?

Ans : In first case : $a = \dfrac{F}{m}$

In first case : $a' = \dfrac{F/2}{m + m}$

$$a' = \frac{1}{4} \cdot \frac{F}{m}$$

$$= \frac{1}{4} a$$

Distinguish between force and momentum

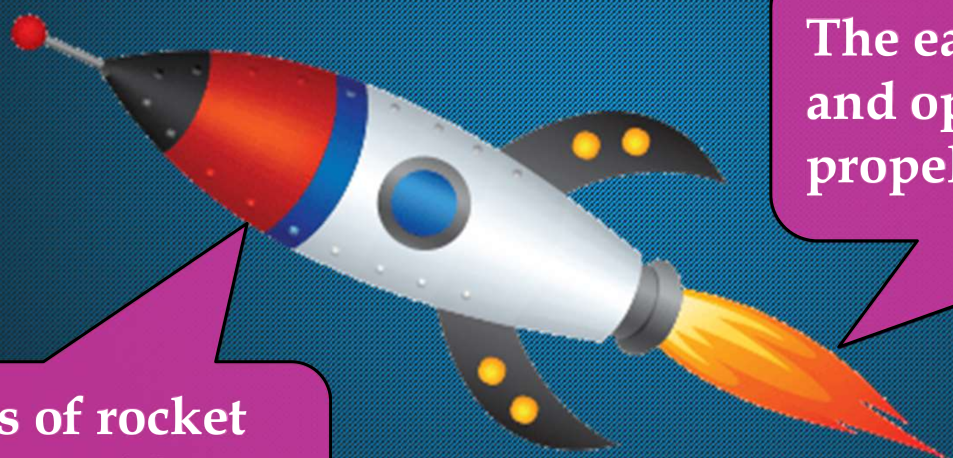
FORCE	MOMENTUM
1. It is a physical quantity that changes or tends to change the state of rest or of uniform motion of a body in a straight line.	1. It is the product of mass and velocity of the body.
2. The unit of force is newton in the MKS system and dyne in the CGS system.	2. In the MKS system, it is kg– m/s and g–cm/s in CGS system.
3. Force = mass × acceleration.	3. Momentum = mass × velocity

LAWS OF MOTION

- **Newton's 3rd law of motion**

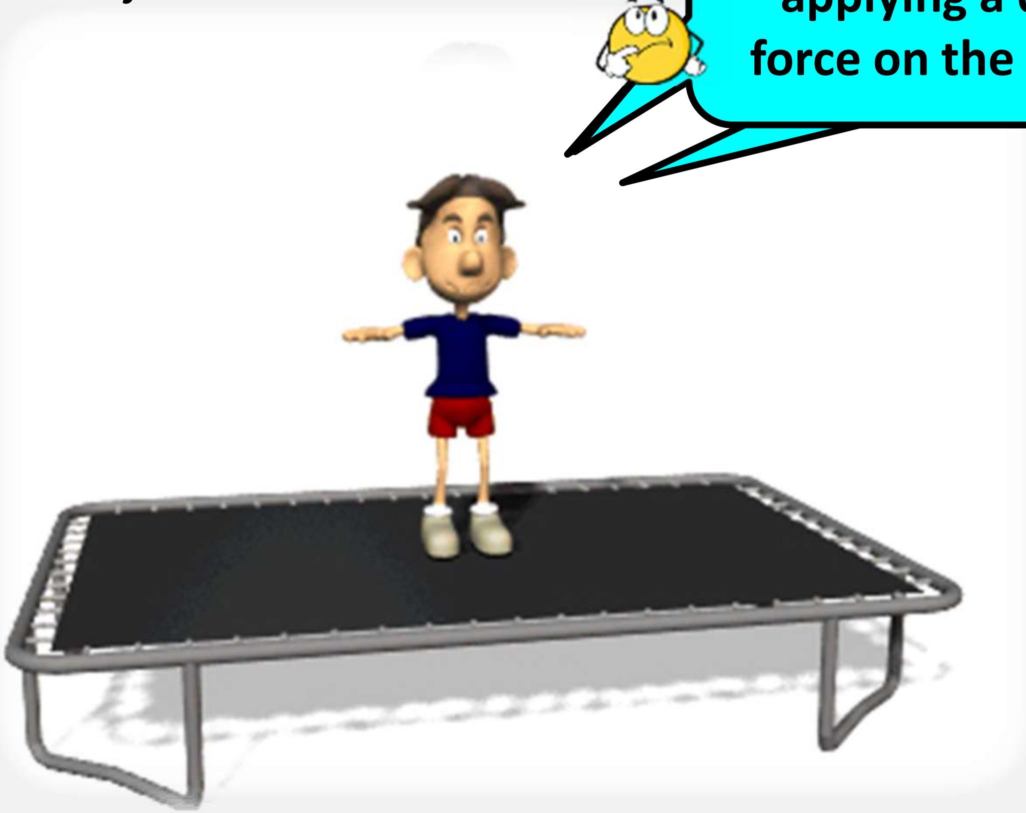
NEWTON'S THIRD LAW OF MOTION

The third law of motion states that every action force has an equal and opposite reaction force which acts simultaneously.



What does Newton want to say in his Third Law?

When he is jumping he is applying a downward force on the trampoline.



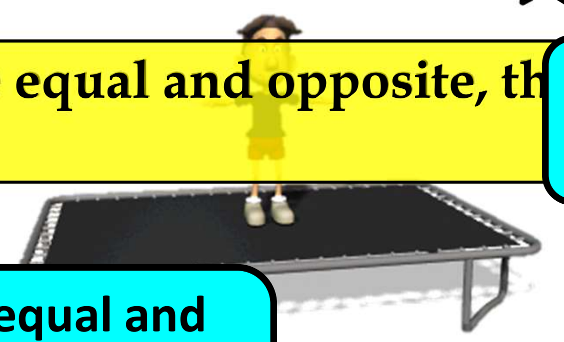
The Law speaks about :

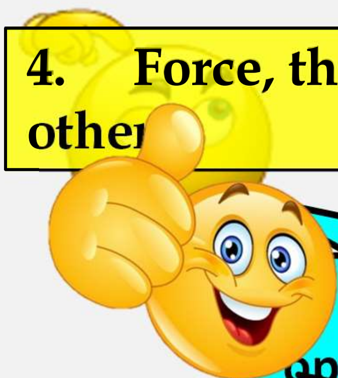
1. Interaction between bodies.

2. These forces act in pairs. One force cannot e

3. Action and reactio

4. Force, though they are equal and opposite, th
other





Boy and trampoline.

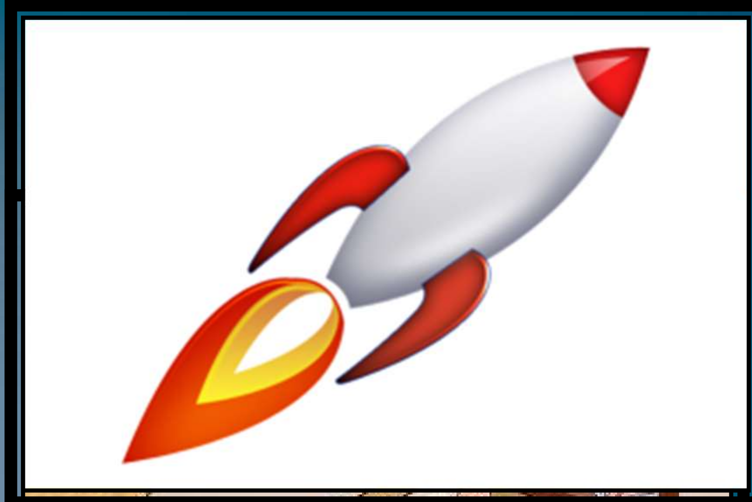
At the same time. There is no delay

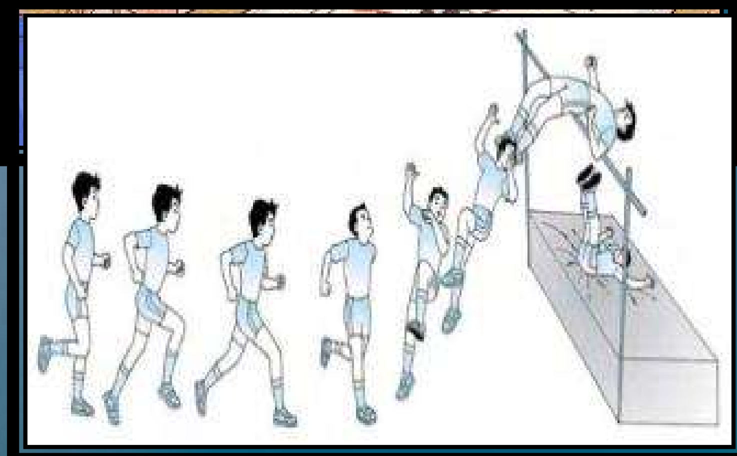
the forces are equal and opposite they should cancel

They do not act on the same object and hence cannot cancel each other’s effect.

US REVISE THE THREE RULES

COLUMN - 1	COLUMN - 2
Newton's first law of motion	Describe the relationship between the forces on two interacting objects.
Newton's second law of motion	Gives an idea of the effects of force.
Newton's third law of motion	Also called as law of inertia.





Since action and reaction forces are always equal in magnitude and opposite in direction, how can anything ever be accelerated?

Or

"Action and reaction are equal and opposite but even then they do not cancel each other." Give reason.

Ans : This is because action and reaction act on different bodies.

A man is at rest in the middle of a pond on perfectly frictionless ice. How can he get himself to the shore?

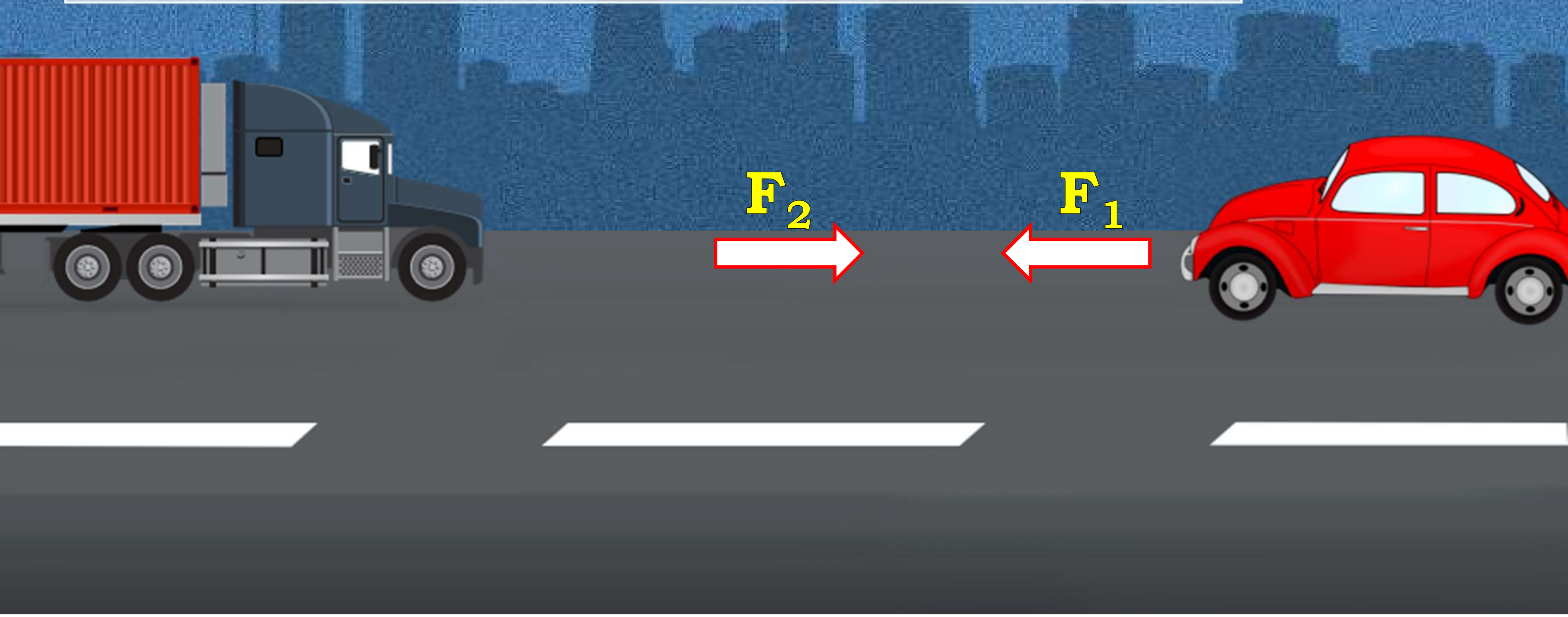
Ans : If the man throws away his shirt in a direction opposite to the desired direction of motion, he can get himself to the shore.

LAWS OF MOTION

- **Law of conservation of momentum**

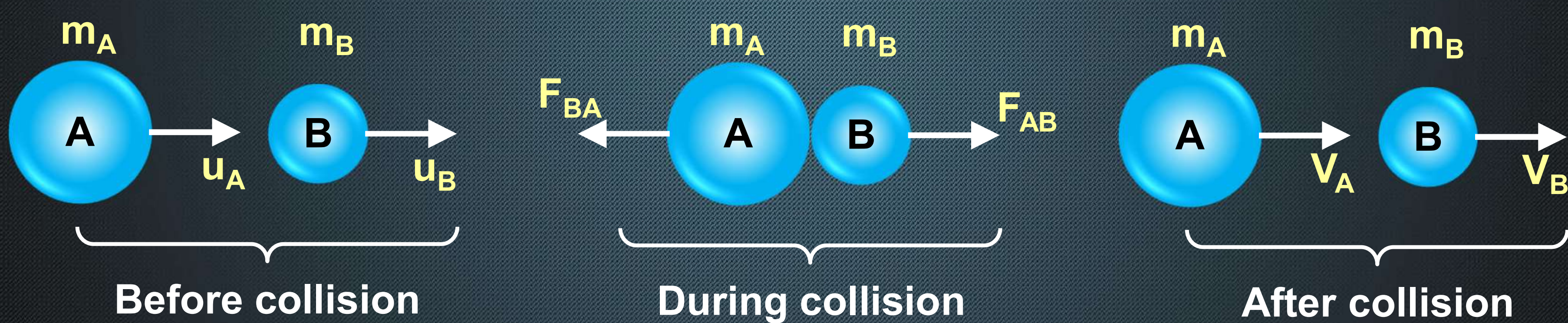
Law of conservation of momentum

When two objects collide, the total momentum before collision is equal to the total momentum after collision



Deduce the law of conservation of momentum from Newton's third law of motion.

Ans : As shown in Fig. consider two bodies A and B of masses m_A and m_B moving in the same direction along a straight line with velocities u_A and u_B respectively such that $u_A > u_B$. They collide for time t. After collision, let their velocities becomes v_A and v_B.



Force exerted by A on B is

$$F_{AB} = \text{Rate of change of momentum of A} = \frac{m_A(v_A - u_A)}{t}$$

Force exerted by B on A is

$$F_{BA} = \text{Rate of change of momentum of B} = \frac{m_B(v_B - u_B)}{t}$$

According to Newton's third law of motion,

$$\text{Action} = -\text{Reaction}$$

$$F_{AB} = -F_{BA}$$

$$\frac{m_A(v_A - u_A)}{t} = -\frac{m_B(v_B - u_B)}{t}$$

$$m_Av_A - m_Au_A = -m_Bv_B + m_Bu_B$$

$$m_Au_A + m_Bu_B = -m_Av_A - m_Bv_B$$

$$\text{Total momentum before collision} = \text{Total momentum after collision}$$

Thus total momentum of the two bodies is conserved provided no external force acts on them. This proves the law of conservation of momentum.

LAWS OF MOTION

- **Conservation of momentum while firing a gun**

CONSERVATION OF MOMENTUM WHEN FIRING A GUN

Mass — Mass of Bullet (m_1), Mass of Gun (m_2)

Initial velocity — (u_1), Initial velocity of Gun (Before firing) (u_2)

Final velocity — Final velocity of Bullet (After firing) (v_1), Final velocity of Gun (After firing) (v_2)

CONSERVATION OF MOMENTUM WHEN FIRING A GUN

Total final momentum = Total initial momentum

$$m_1 v_1 + m_2 v_2 = 0$$

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

Hence, Total initial momentum is zero

This backward motion of the gun is called **RECOIL**

As gun and bullet are initially at rest, initially velocity is zero.

$$m_2 v_2 = -m_1 v_1$$

$$v_2 = \frac{-m_1 v_1}{m_2}$$

Negative indicates that the gun will move in the opposite direction

The velocity v_2 is called **RECOIL VELOCITY**

LAWS OF MOTION

- Type A - Numerical

TYPE - A

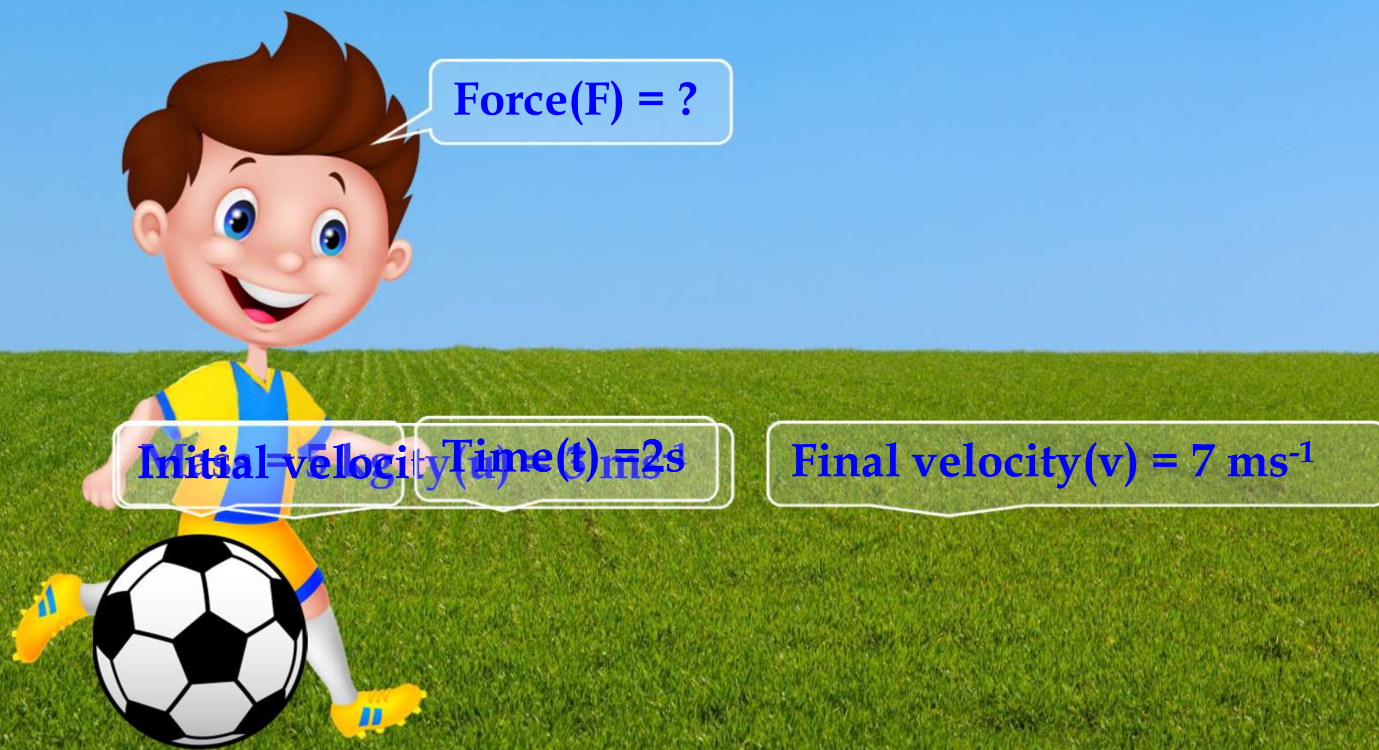
$$F = ma$$

NUMERICAL

$$a = \frac{v-u}{t}$$

1

A constant force acts on an object of mass 5 kg for a duration of 2 s. It increases the object's velocity from 3 m s^{-1} to 7 m s^{-1} . Find the magnitude of the applied force.



1

A constant force acts on an object of mass 5 kg for a duration of 2 s. It increases the object's velocity from 3 m s^{-1} to 7 m s^{-1}. Find the magnitude of the applied force.

Given :

Mass of the object (m) = 5kg

Time (t) = 2s

Initial velocity (u) = 3 ms^{-1}

Final velocity (v) = 7 ms^{-1}

To find :

Force (F) = ?

Formulae :

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

Solution :

$$a = \frac{(7 - 3)}{2}$$

$$\therefore a = \frac{4}{2}$$

$$\therefore a = 2ms^{-2}$$

$$F = ma$$

$$= 5 \times 2$$

$$= 10N$$

Ans :

Force acting on the object is 10 N.

LAWS OF MOTION

- Type A - Numerical

2

Which would require a greater force - accelerating a 2 kg mass at $5ms^{-2}$ or a 4 kg mass at $2ms^{-2}$?

	A	B
Mass	m_1=2 kg	m_2=4 kg
Acceleration	a_1=5 ms^{-2}	a_2=2 ms^{-2}

Who has a greater force?

2 Which would require a greater force - accelerating a $\boxed{2\ kg}$ mass at $\boxed{5ms^{-2}}$ or a $\boxed{4\ kg}$ mass at $\boxed{2ms^{-2}}$?

Given :

Mass of 1^{st} object (m_1) = 2 kg

Mass of the 2^{nd} object (m_2) = 4 kg

Acceleration of the 1^{st} object (a_1) = $5ms^{-2}$

Acceleration of the 2^{nd} object (a_2) = $2ms^{-2}$

To find : $F_1 > F_2$ or $F_2 > F_1$

Formula : $F = ma$

Solution :

(i) $F_1 = m_1 a_1$

$\therefore F_1 = 2 \times 5$

$\therefore F_1 = 10N$

(ii) $F_2 = m_2 a_2$

$\therefore F_2 = 4 \times 2$

$\therefore F_2 = 8N$

$F_1 > F_2$

Ans :

Accelerating a 2 kg mass at $5ms^{-2}$ requires a greater force.

3

Two persons manage to push a motorcar of mass $\boxed{1200\text{ kg}}$ at a uniform velocity along a level road. The same motorcar can be pushed by three persons to produce an acceleration of $\boxed{0.2\text{ ms}^{-2}}$. With what force does each person push the motorcar?

(Assume that all persons push the motorcar with the same muscular effort.)

Given : $m = 1200\text{ kg}$

$a = 0.2\text{ m s}^{-2}$

Ans : Each person applies a force of magnitude 80 N

To find : $F = ?$

Formula : $F = ma$

Solution : $F = ma$

$\therefore \quad F = 1200 \times 0.2$

$\therefore \quad F = 240\text{ N}$

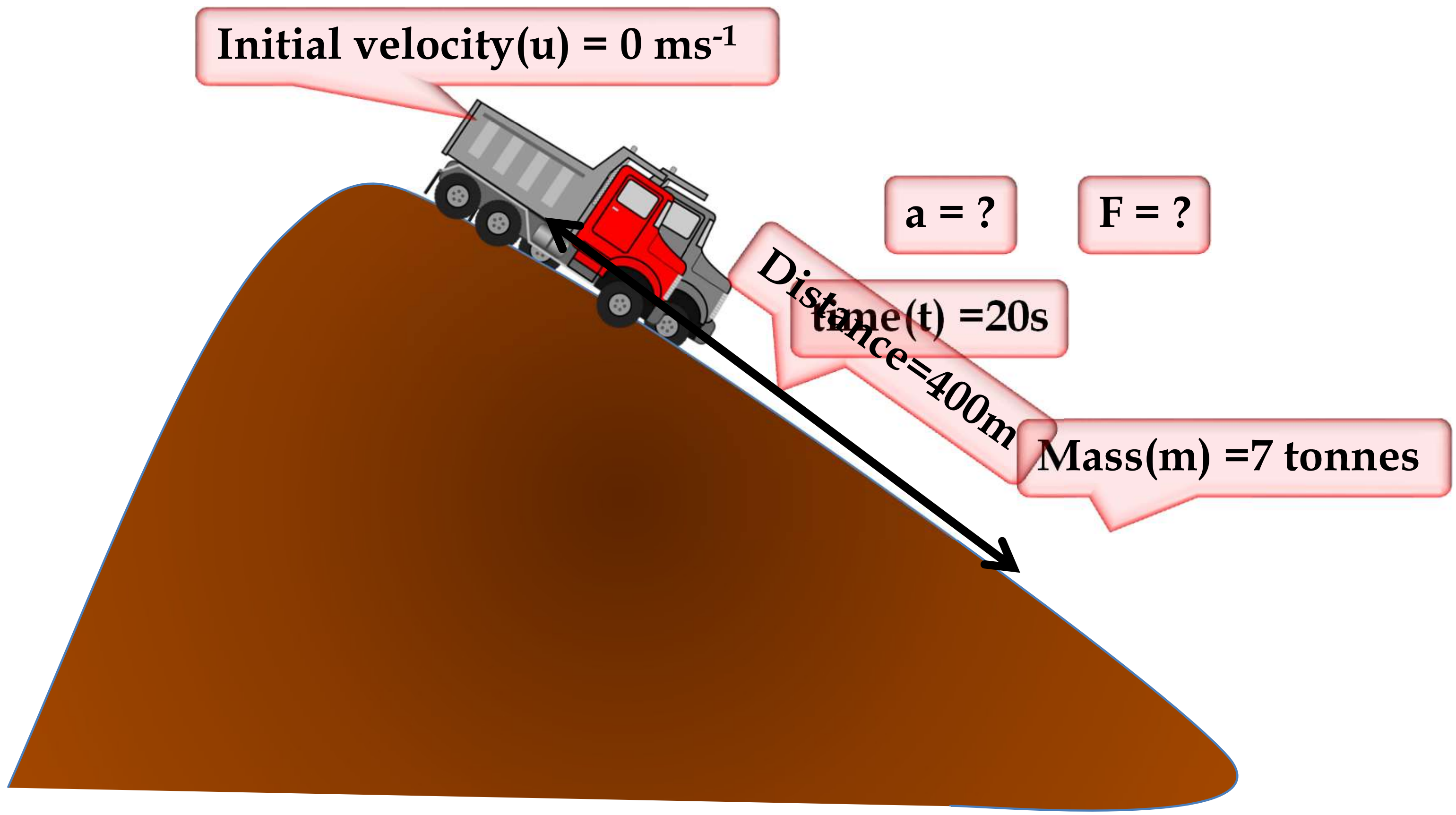
Force Exerted by Each Person = $\dfrac{240}{3} = 80\text{ N}$

LAWS OF MOTION

- Type A - Numerical

4

A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20s. Find its acceleration. Also find the force acting on it if its mass is 7 tonnes. **(Hint : 1 tonne = 1000 kg.)**



4 A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20s. Find its acceleration. Also find the force acting on it if its mass is 7 tonnes (Hint:1 tonne = 1000 kg.)

Given :

Initial velocity (u) = $0\ ms^{-1}$

Distance travelled (s) = 400 m

Time (t) = 20 s

Mass of truck (m) = 7 tonnes = 7000 kg

To find :

Acceleration (a) = ?

Force (F) = ?

Formulae : (i) $s = ut + \frac{1}{2}at^2$ (ii) $F = ma$

Solution : (i) $s = ut + \frac{1}{2}at^2$

$$400 = 0 \times 20 + \frac{1}{2}\ a \times 20 \times 20$$

$$400 \times 2 = 400\ a$$

$$\therefore \quad a = \frac{400 \times 2}{400} = 2ms^{-2}$$

(ii) $F = ma$

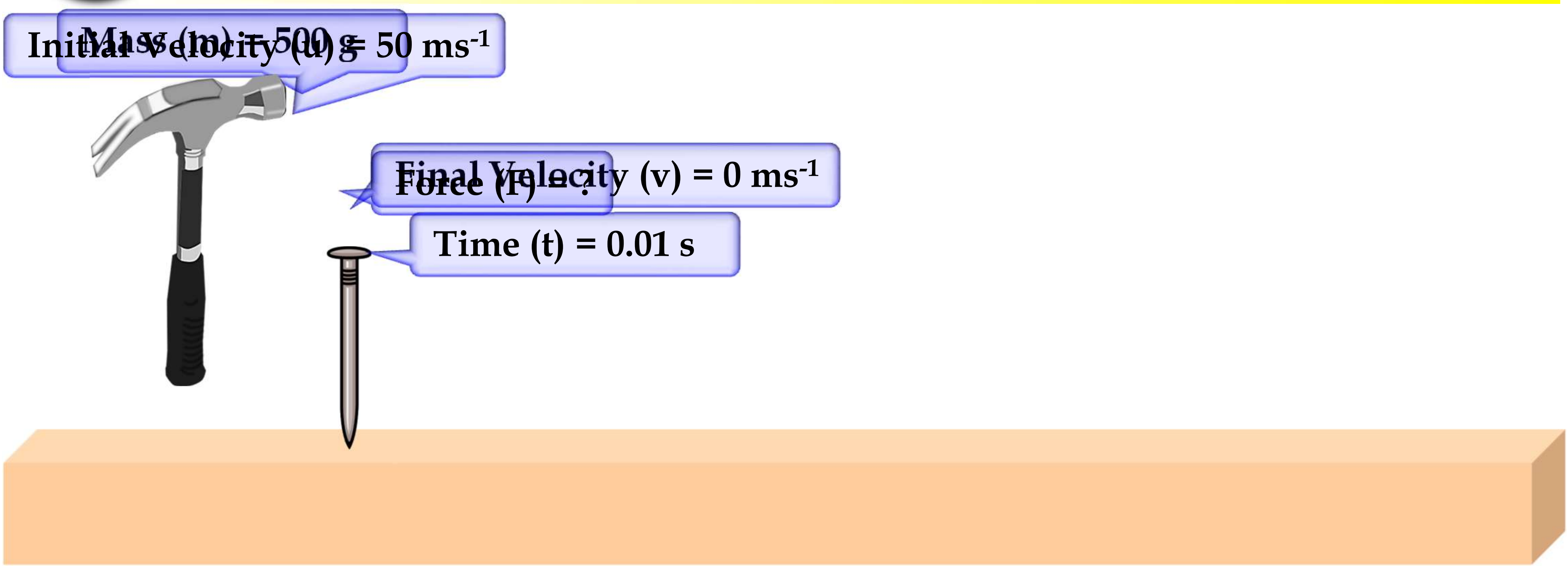
$$\therefore \quad F = 7000 \times 2$$

$$\therefore \quad F = 14000N$$

Ans :

The truck moves with an acceleration of $2ms^{-2}$ and the force acting on it is 14000 N .

5 A hammer of mass 500 g, moving at 50 ms^{-1}, strikes a nail. The nail stops the hammer in a very short time of 0.01 s. What is the force of the nail on the hammer?



5

A hammer of mass 500 g, moving at 50 ms^{-1}, strikes a nail. The nail stops the hammer in a very short time of 0.01 s. What is the force of the nail on the hammer?

Given :

$m = 500\text{ g} = \frac{500}{1000}$

$= 0.5\text{ kg}$

$u = 50\text{ ms}^{-1}$

$t = 0.01\text{ s}$

$v = 0\text{ ms}^{-1}$

To Find : $F = ?$

Formulae : (i) $a = \frac{v - u}{t}$

(ii) $F = ma$

Solution : $a = \frac{v - u}{t} = \frac{0 - 50}{0.01}$

$\therefore\ a = \frac{-50}{0.01}$

$\therefore\ a = -5000\text{ m s}^{-2}$

$F = ma$

$\therefore\ F = 0.5 \times -5000$

$\therefore\ F = -2500\text{N}$

The –ve sign shows that the body is retarding

Ans:

The force acting on the nail is -2500N. The negative sign shows that friction force being exerted.

LAWS OF MOTION

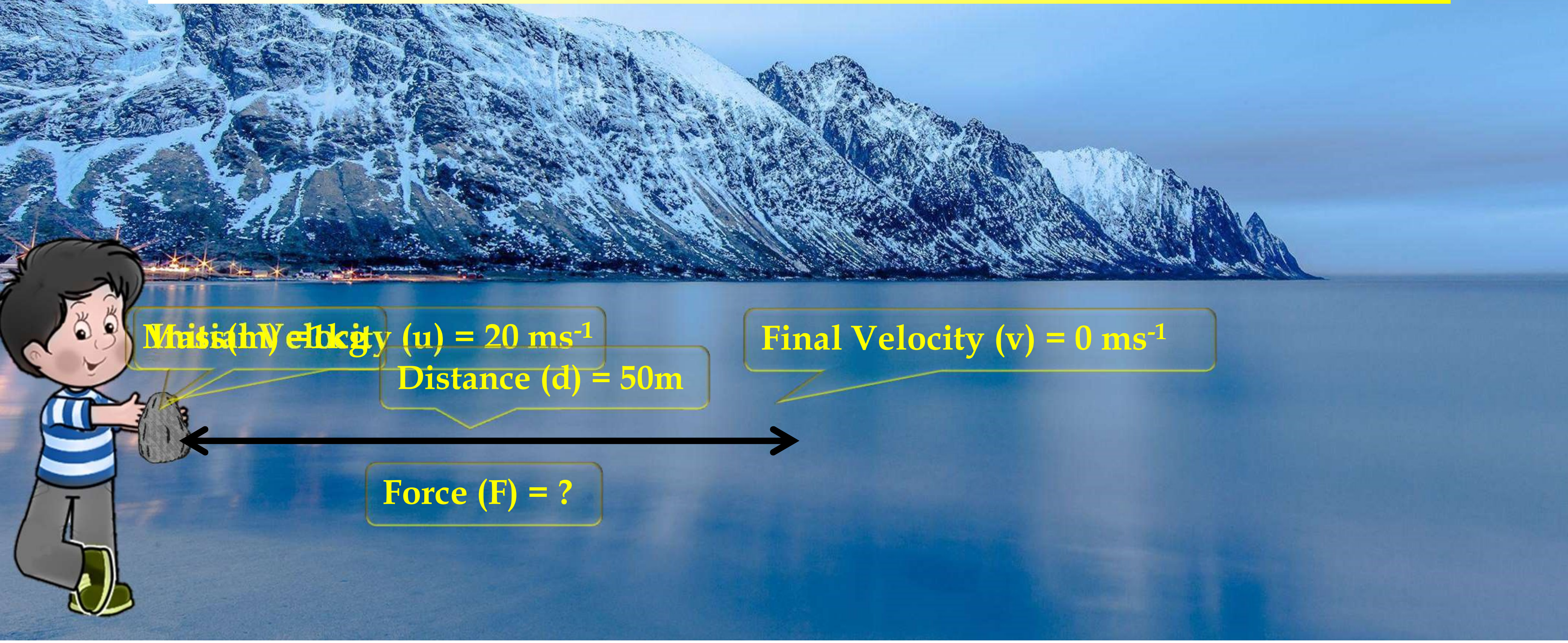
- Type A - Numerical

6

A stone of 1 kg is thrown with a velocity of $20ms^{-1}$ across the frozen surface of a lake and comes to rest after travelling a distance of 50 m. What is the force of friction between the stone and the ice?

6

A stone of 1 kg is thrown with a velocity of $20 ms^{-1}$ across the frozen surface of a lake and comes to rest after travelling a distance of 50 m. What is the force of friction between the stone and the ice?



6

A stone of 1 kg is thrown with a velocity of 20m s^{-1} across the frozen surface of a lake and comes to rest after travelling a distance of 50 m. What is the force of friction between the stone and the ice?

Given: Mass of the stone (m) = 1 kg
Initial velocity (u) = 20 ms^{-1}
Final velocity (v) = 0 ms^{-1}
Distance travelled (s) = 50 m

To Find: Force of friction (F) = ?

Formulae: (i) $F = ma$
(ii) $v^2 = u^2 + 2as$

Solution : (i) $v^2 = u^2 + 2as$

$2as = v^2 - u^2$

$2as = 0^2 - 20^2$

$$a = \frac{\overset{-8}{-\cancel{400}}}{2 \times \cancel{50}}$$

$\therefore \quad a = -4ms^{-2}$ [-ve sign shows the retardation]

(ii) $F = ma$

$\therefore \quad F = 1 \times -4$

$\therefore \quad F = -4N$

Ans: Force of friction between ice and stone is – 4N

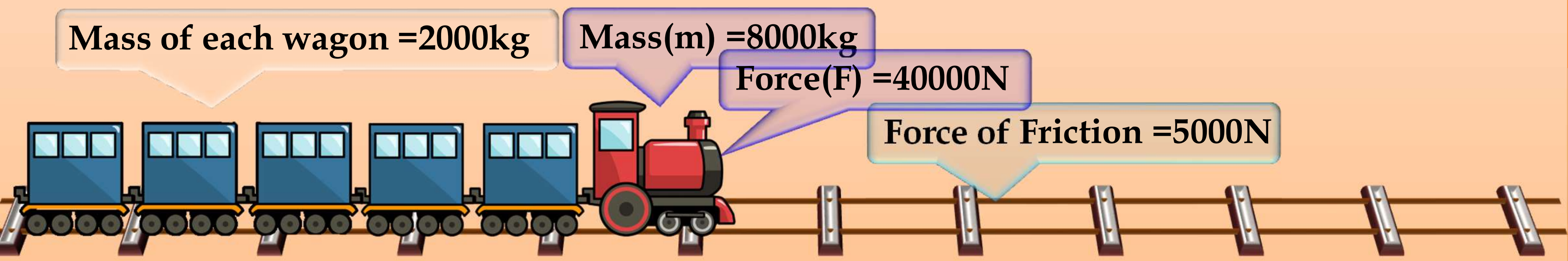
The –ve sign shows that the Force is acting in the opposite direction of the motion

LAWS OF MOTION

- Type A - Numericals

7

8000 kg engine pulls a train of 5 wagons, each of 2000 kg along a horizontal tracks. If the engine exerts a force of 40000 N and the track offers a friction force of 5000 N. Then calculate: (a) The net accelerating force (b) The acceleration of the train (c)The force of wagon 1 on wagon 2.



7 A 8000 kg engine pulls a train of 5 wagons, each of 2000 kg along a horizontal tracks. If the engine exerts a force of 40000 N and the track offers a friction force of 5000 N. Then calculate: (a)The net accelerating force (b)The acceleration of the train (c)The force of wagon 1 on wagon 2.

Given : Mass of engine = 8000kg Mass of each wagon = 2000kg

Force Exerted By Engine = 40000N Friction force = 5000N

To Find : (a) Net accelerating force = ? (b) Acceleration of the train = ? (c) The force of wagon 1 on wagon 2 = ?

Formulae : (a) Net accelerating force = Force exerted by engine - Force exerted by tracks

(b) F = ma

Solution :

(a) Net accelerating force = Force exerted by engine - Force by

= 40000 - 5000

= 35000N

Total Mass = Mass of Engine + Total mass of 5 Wagons

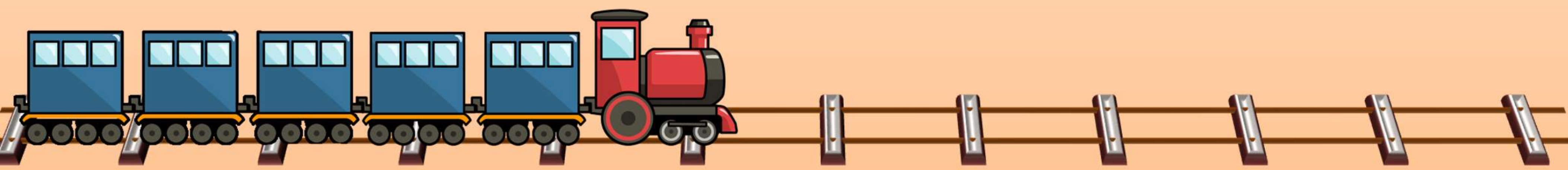
Total Mass = 8000 + 5(2000)

= 8000 + 10000

$= \frac{F}{m}$

$\frac{35\cancel{000}}{18\cancel{000}} = 1.94\ ms^{-2}$

(c) Force of Wagon 1 on Wagon 2 = Mass of 4 wagons behind wagon 1 × a



LAWS OF MOTION

- Type A - Numerical

8

An Auto Mobile vehicle has mass of 1500kg. What must be the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of 1.7 ms^{-2} ?

8

An Auto Mobile vehicle has mass of $\boxed{1500kg.}$ What must be the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of $\boxed{1.7\ ms^{-2}}$?

Given :- Mass of automobile (m) = 1500 kg

acceleration (a) = $-1.7ms^{-2}$

To Find: Force of friction (F) = ?

Formula: $F = ma$

Solution :

$F = ma$

$F = 1500 \times -1.7$

$F = -2550\ N$

The –ve sign shows that the Force is acting in the opposite direction of the motion

Answer: The Force between the vehicle and the road is -2550 N.

9

A force of 5N gives a mass m_1, an acceleration of $10 ms^{-2}$ and a mass m_2, an acceleration of $20 ms^{-2}$. What acceleration would it give if both the masses were tied together?

Given: $a_1 = 10\ ms^{-2}$ $\quad a_2 = 20\ ms^{-2}$

$F = 5\ N$

To Find: Total acceleration (a) = ?

Formula: (i) $F = ma$

Solution:

$$F = ma$$

$$F = m_1 \times a_1$$

$$m_1 = \frac{F}{a_1}$$

$$m_1 = \frac{5}{10} = \frac{1}{2} = 0.5kg$$

$$F = m_2 \times a_2$$

$$m_2 = \frac{F}{a_2}$$

$$m_2 = \frac{5}{20} = \frac{1}{4} = 0.25kg$$

Total Mass $= 0.5 + 0.25 = 0.75kg$

$$F = ma$$

$$a = \frac{F}{m} = \frac{5}{0.75} = 6.67\ ms^{-2}$$

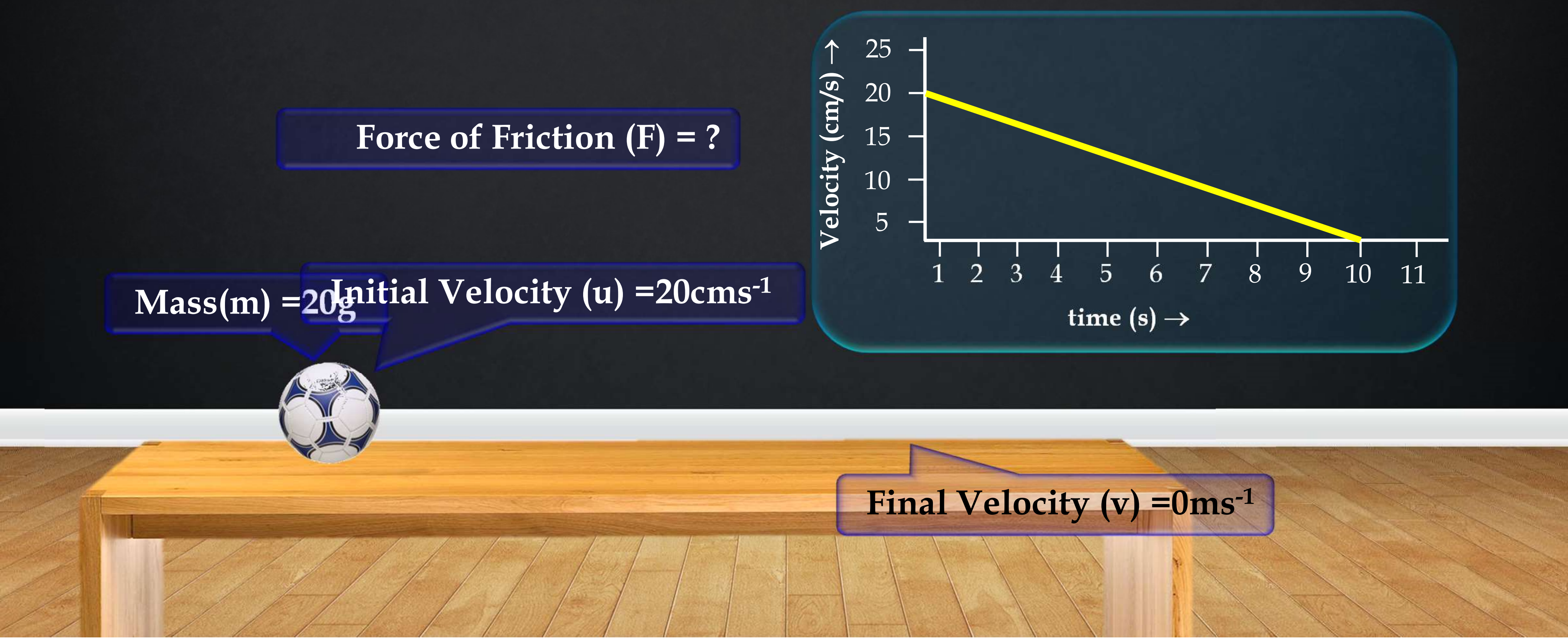
Ans: The total acceleration produced is $6.67\ ms^{-2}$.

LAWS OF MOTION

- **Type A - Numericals**

10

The velocity-time graph of a ball of mass 20g moving along a straight line on a long table is given in the figure. How much force does the table exert on the ball to bring it to rest?



10 The velocity-time graph of a ball of mass $\boxed{20g}$ moving along a straight line on a long table is given in the figure. How much force does the table exert on the ball to bring it to rest?

Given : Mass of ball (m) $= 20\ g = \frac{20}{1000} = 0.02\ kg$

Initial velocity (u) $= 20\ cms^{-1} = 0.2\ ms^{-1}$

Final velocity (v) $= 0\ cms^{-1} = 0\ ms^{-1}$

Time taken (t) $= 10\ s$

To Find : Force of friction on the ball (F) = ?

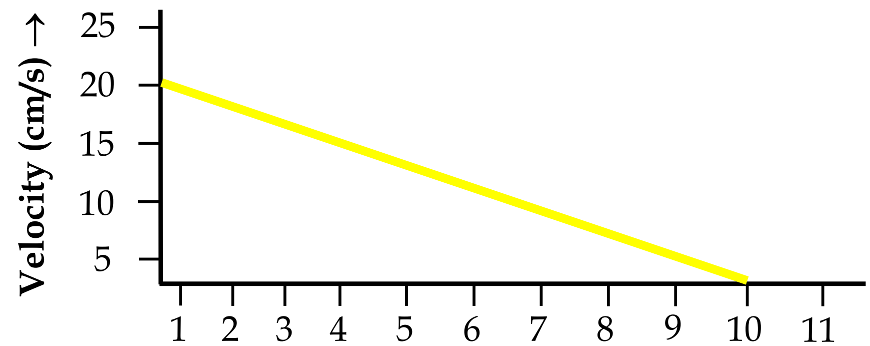
Formulae : (a) $F = m\,a$ (b) $a = \frac{v - u}{t}$

Solution :

$$a = \frac{0 - 0.2}{10}$$

$$a = -0.02ms^{-2}$$

Acceleration of the ball in – $0.02ms^{-2}$



$F = m\,a$

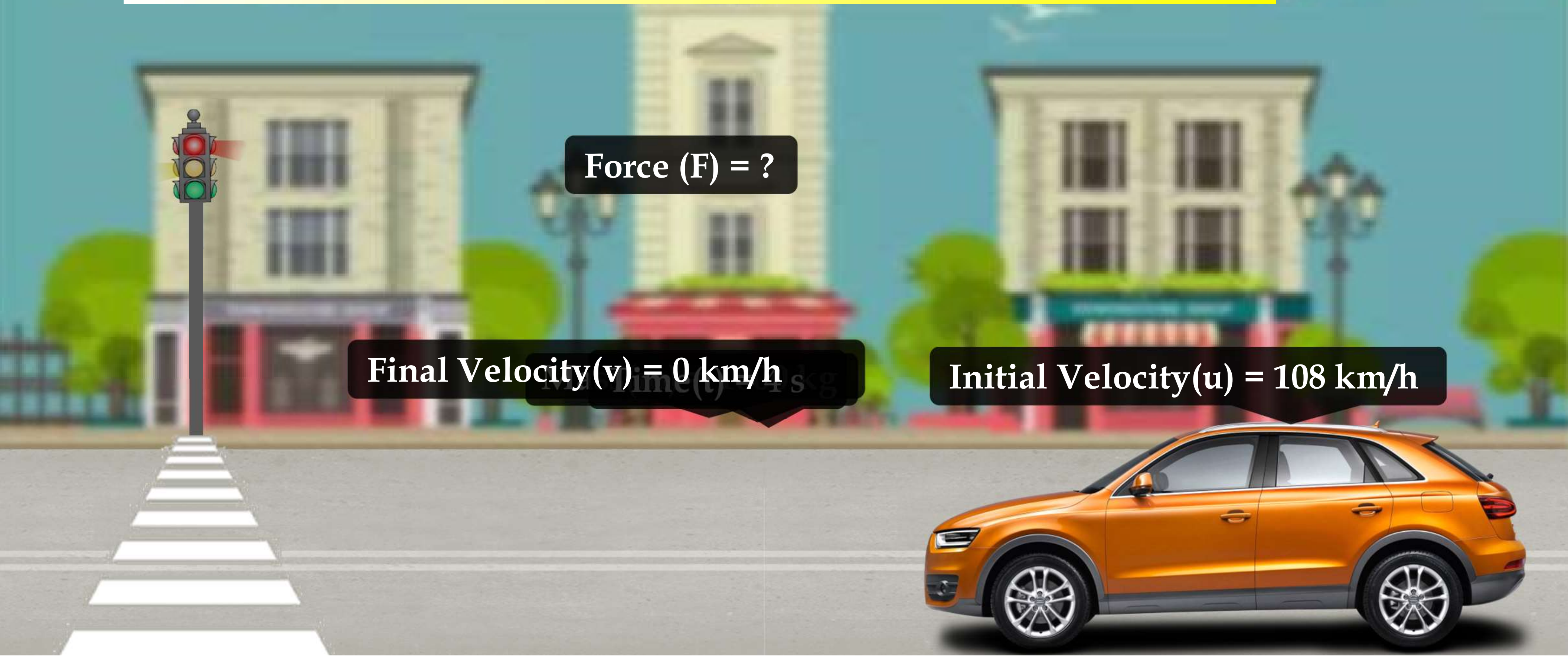
$\therefore F = 0.02 \times (-0.02) = -0.0004\ N$

Ans:

Force exerted is -0.0004N. The negative sign shows that friction force is exerted by the table.

11

A motorcar is moving with a velocity of 108km/h and it takes 4s to stop after the brakes are applied. Calculate the force exerted by the brakes on the motorcar if its mass along with the passengers is 1000kg.



11

A motorcar is moving with a velocity of 108km/h and it takes 4s to stop after the brakes are applied. Calculate the force exerted by the brakes on the motorcar if its mass along with the passengers is 1000kg.

Given :

$u = 108 \text{ km/h} = 108 \times \frac{5}{18} = 30 \text{ ms}^{-1}$

$v = 0 \text{ ms}^{-1}$

$t = 4\text{s}$

$m = 1000\text{kg}$

To Find: $F = ?$

Formulae: (i) $a = \frac{v - u}{t}$ (ii) $F = ma$

Solution:

$a = \frac{v \ldots}{t \ldots}$

The –ve sign shows that the body is retarding

$\therefore a = -7.5 \text{ ms}^{-2}$

$F = ma$

$F = 1000 \times -7.5$

$F = -7500 \text{ N}$

Ans:

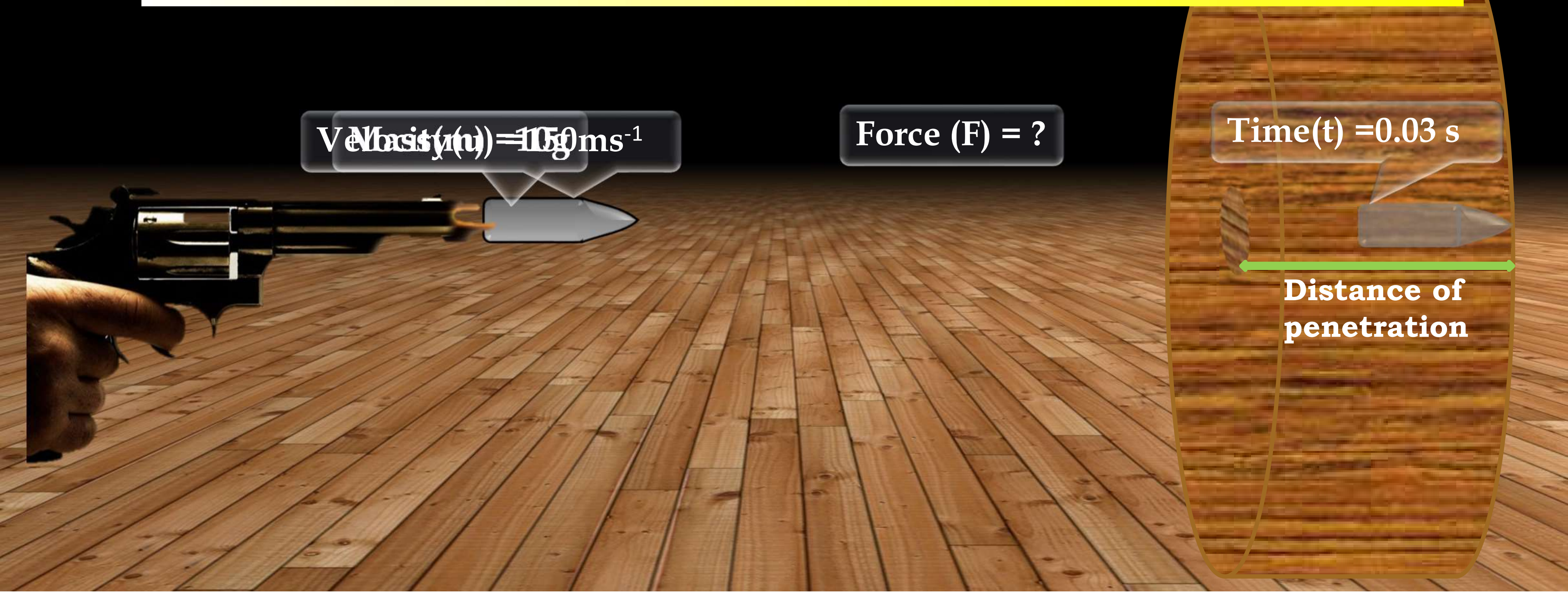
Force exerted by the brakes is 7500N. Negative sign indicates retarding force.

LAWS OF MOTION

- **Type A - Numericals**

12

A bullet of mass 10 g travelling horizontally with a velocity of 150 ms^{-1} strikes a stationary wooden block and comes to rest in 0.03 s. Calculate the distance of penetration of the bullet into the block. Also calculate the magnitude of the force exerted by the wooden block on the bullet.



12

A bullet of mass $\boxed{10\ g}$ travelling horizontally with a velocity of $\boxed{150\ ms^{-1}}$ strikes a stationary wooden block and comes to rest in $\boxed{0.03\ s.}$ Calculate the distance of penetration of the bullet into the block. Also calculate the magnitude of the force exerted by the wooden block on the bullet.

Given :

mass (m) = 10 g = 0.01 kg

Initial velocity (u) = 150 ms^{-1}

Final velocity (v) = 0 ms^{-1}

time taken (t) = 0.03 s

To Find :

(a) distance travelled (s) = ?

(b) force exerted (F) = ?

Formulae:

$v = u + at$

$v^2 = u^2 + 2as$

$F = ma$

Solution:

$v = u + a t,\ 0 = 150 + a \times 0.03$

$0.03\ a = -150$

$a = \dfrac{-150}{0.03} = \dfrac{\overset{-5000}{\cancel{-15000}}}{\cancel{3}} = -5000\ ms^{-2}$

-ve Sign shows that it is retardation

$v^2 = u^2 + 2as$

$2as = v^2 - u^2$

$2as = 0 - u^2$

$s = \dfrac{\cancel{-}(150 \times 150)}{2} = \dfrac{9}{4} = 2.25$

Distance of penetrat

-ve Sign shows that it is Force of Friction

$F = ma$

$F = 0.01 \times -5000 = -50\ N$

LAWS OF MOTION

- **Type B - Numerical**

TYPE - B

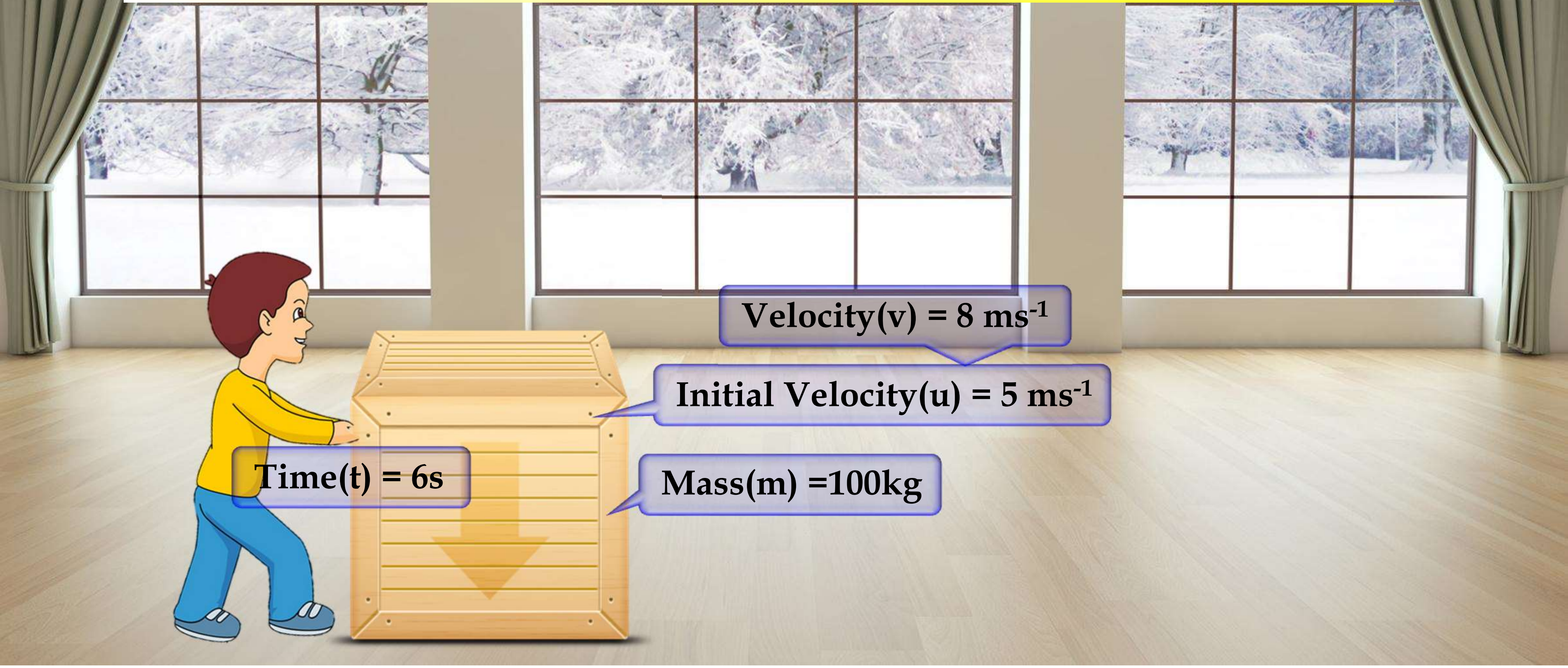
$p = mv$

NUMERICAL

$\Delta p = mv - mu$

1

An object of mass 100 kg is accelerated uniformly from a velocity of 5 ms^{-1} to 8 ms^{-1} in 6s. Calculate the initial and final momentum of the object. Also find the magnitude of the force exerted on the object.



1 An object of mass $\boxed{100 \text{ kg}}$ is accelerated uniformly from a velocity of $\boxed{5 \text{ ms}^{-1}}$ to $\boxed{8 \text{ ms}^{-1}}$ in $\boxed{6\text{s}}$. Calculate the initial and final momentum of the object. Also find the magnitude of the force exerted on the object.

Given:

Mass (m) = 100 kg

Initial velocity (u) = 5 ms^{-1}

Final velocity (v) = 8 ms^{-1}

Time taken (t) = 6 s

To Find:

(a) Initial momentum (p_1) = ?

(b) Final momentum (p_2) = ?

(c) Force exerted (F) = ?

Formulae:

(a) $p = mv$

(b) $F = ma$

(c) $a = \dfrac{v-u}{t}$

Solution:

(a) Initial momentum (p_1) = mu

$= 100 \times 5 = 500 \text{ kg ms}^{-1}$

(b) Final momentum (p_2) = mv

$= 100 \times 8 = 800 \text{ kg ms}^{-1}$

(c) $a = \dfrac{v-u}{t}$

$\therefore \; a = \dfrac{8-5}{6}$

$\therefore \; a = \dfrac{\cancel{3}^{\,1}}{\cancel{6}_{\,2}}$

$\therefore \; a = 0.5 \text{ ms}^{-2}$

$F = ma$

$\therefore \; F = 100 \times 0.5$

$\therefore \; F = 50 \text{ N}$

Force exerted is 50 N

2

A hockey ball of mass 200 g travelling at 10 ms^{-1} is struck by a hockey stick so as to return it along its original path with a velocity at 5 ms^{-1}. Calculate the change of momentum occurred in the motion of the hockey ball by the force applied by the hockey stick.

Given: $m = 200g = \frac{200}{1000} = 0.2$ kg

$u = 10$ m/s $\quad v = -5$ m/s

The negative sign indicates that the object is moving in opposite direction

To Find: Change of momentum (Δp) = ?

Formulae: $\Delta p = mv - mu$

Solution:

$\Delta p = mv - mu$

$\Delta p = (0.2 \times -5) - (0.2 \times 10)$

$\Delta p = -1 - 2$

$\Delta p = -3$ $kgms^{-1}$

The negative sign indicates that the object is moving in opposite direction

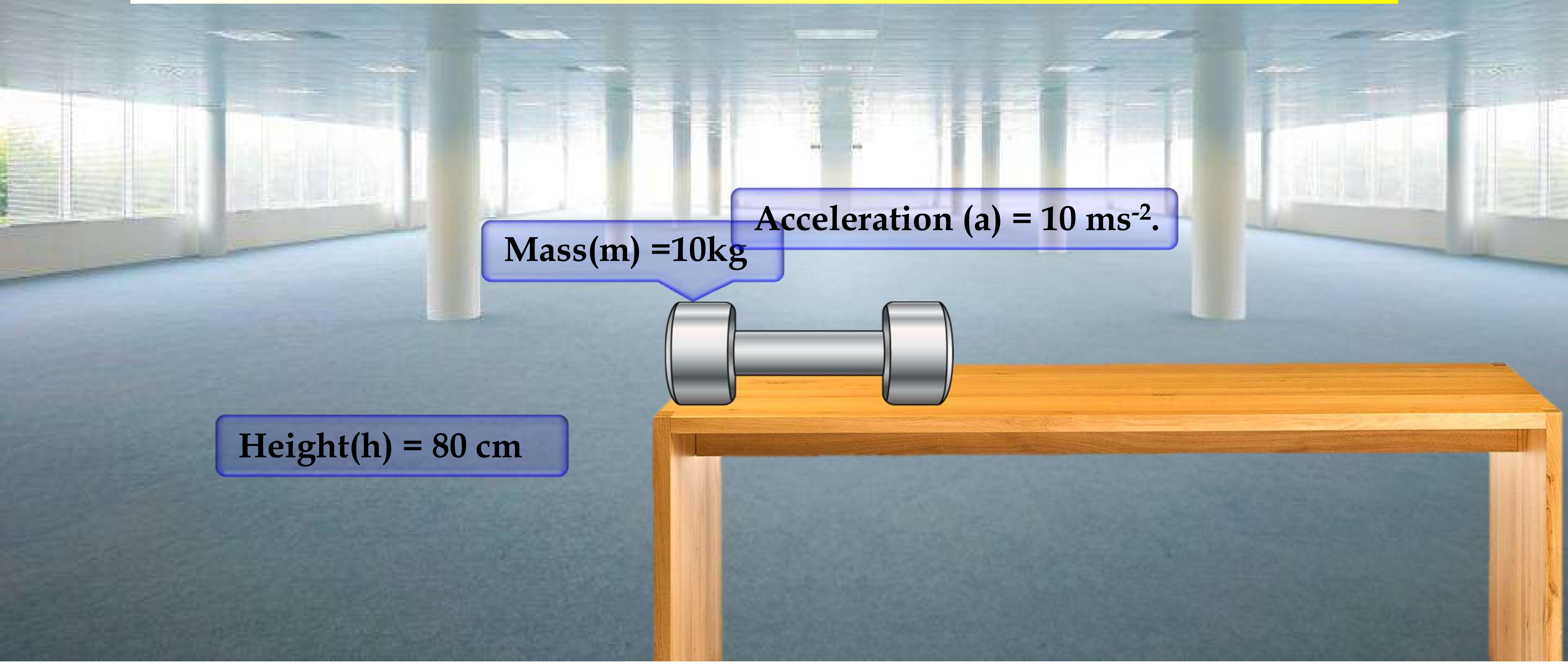
Ans: Change of momentum is 3$kgms^{-1}$.

LAWS OF MOTION

- **Type B - Numerical**

3

How much momentum will a dumb-bell of mass 10 kg transfer to the floor if it falls from a height of 80 cm ? Take its downward acceleration to be 10 ms^{-2}.



3

How much momentum will a dumb-bell of mass $\boxed{10\ kg}$ transfer to the floor if it falls from a height of $\boxed{80\ cm}$? Take its downward acceleration to be $\boxed{10\ ms^{-2}}$.

Given :

mass (m) = 10 kg

height (s) = 80 cm

$= \frac{80}{100} = 0.8\ m$

Acceleration (a) = $10\ ms^{-2}$

Initial velocity (u) = $0\ ms^{-1}$

To Find : Momentum (p) = ?

Formulae :

a) $p = mv$

b) $v^2 = u^2 + 2as$

Solution :

$$v^2 = u^2 + 2as$$

$$\therefore\ v^2 = 0^2 + 2 \times 10 \times 0.8$$

$$v^2 = 16$$

$$\therefore\ v = \sqrt{16}$$

$$v = 4\ ms^{-1}$$

$$p = mv$$

$$\therefore\ p = 10 \times 4$$

$$\therefore\ p = 40\ kg\ ms^{-1}$$

Ans: The momentum transferred to the floor is $40\ kgms^{-1}$.

4

A motorcar of mass 1200 kg is moving along a straight line with a uniform velocity of 90 km/h. Its velocity is slowed down to 18 km/h in 4 s by an unbalanced external force. Calculate the acceleration and change in momentum. Also calculate the magnitude of the force required.

4

A motorcar of mass $\boxed{1200\ kg}$ is moving along a straight line with a uniform velocity of $\boxed{90\ km/h}$. Its velocity is slowed down to $\boxed{18\ km/h}$ in $\boxed{4\ s}$ by an unbalanced external force. Calculate the acceleration and change in momentum. Also calculate the magnitude of the force required.

Given :

Mass (m) = 1200 kg

Initial velocity (u) = 90 km/h

$$= \cancel{90}^{5} \times \frac{5}{\cancel{18}_{1}}\ m/s$$

$$= 25\ ms^{-1}$$

Final velocity (v) = 18 km/h

$$= \cancel{18}^{1} \times \frac{5}{\cancel{18}_{1}}\ m/s$$

$$= 5\ ms^{-1}$$

Time taken (t) = 4 s

To Find :

(i) Acceleration (a) = ?

(ii) Change in momentum = ?

(iii) Force exerted (F) = ?

Formulae : $a = \frac{v - u}{t}$

Change in momentum = mv - mu F = ma

Solution :

(i) $a = \frac{v - u}{t} = \frac{5 - 25}{4} = \frac{-20}{4} = -5\ ms^{-2}$

(ii) Change in momentum = mv - mu = m(v - u) = 1200 (5 - 25)

$= 1200 \times -20 = -24000\ kg\ ms^{-1}$

(iii) Force exerted (F) = ma = $1200 \times -5 = -6000$ N

Ans: Acceleration is $5 ms^{-2}$ and the change in momentum is $24000 kgms^{-1}$. The magnitude of force is 6000N

LAWS OF MOTION

- **Type C - Numerical**

Type - C

$$m_1u_1 + m_2\,u_2 = m_1v_1 + m_2\,v_2$$

Where,

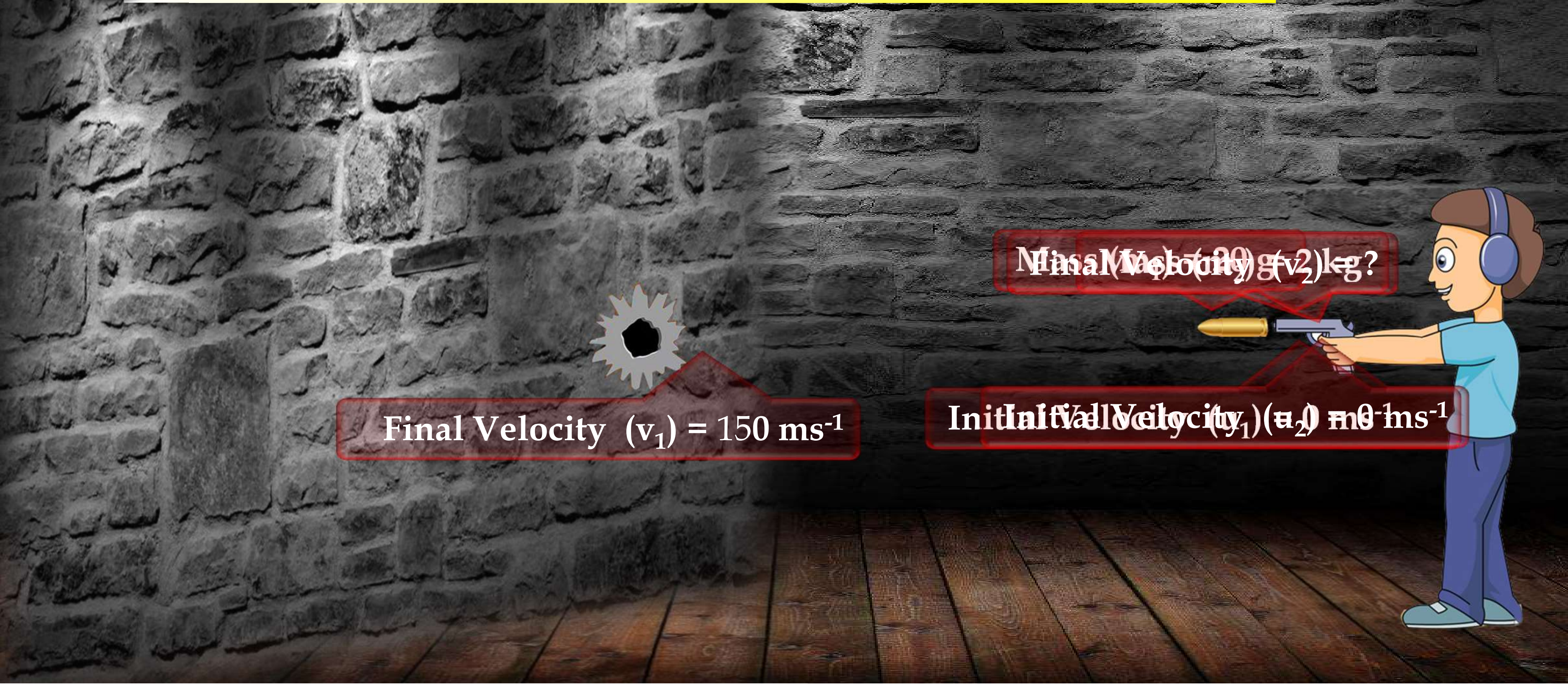
u	=	Initial velocity
m	=	Mass of the body
v	=	Final velocity

Note:

Total Momentum before collision = Total Momentum after collision

1

A bullet of mass 20 g is horizontally fired with a velocity 150 ms^{-1} from a pistol of mass 2 kg. What is the recoil velocity of the pistol?



1

A bullet of mass 20 g is horizontally fired with a velocity 150 ms^{-1} from a pistol of mass 2 kg. What is the recoil velocity of the pistol?

Given:

Mass of the bullet (m_1) = 20 g

= 0.02 kg

Mass of the pistol (m_2) = 2 kg

Initial velocity of bullet (u_1) = 0 ms^{-1}

Initial velocity of pistol (u_2) = 0 ms^{-1}

Final velocity of bullet (v_1) = 150 ms^{-1}

To Find: Recoil velocity of pistol (v_2) = ?

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

Solution:

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

$$(0.02 \times 0) + (2 \times 0) = (0.02 \times 150) + (2 \times v_2)$$

$$0 = (3) + 2v_2$$

$$2v_2 = -3$$

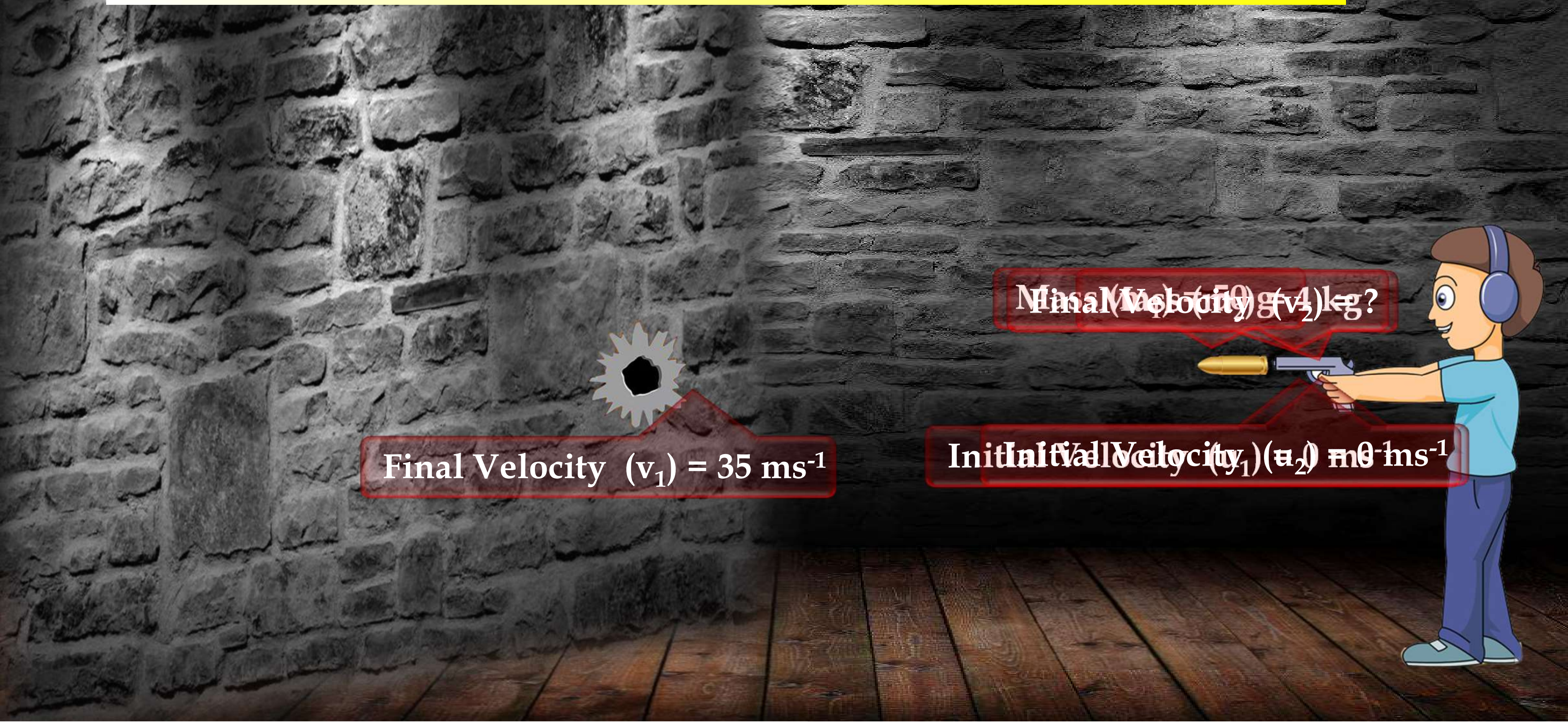
$$\therefore v_2 = \frac{-3}{2}$$

$$\therefore v_2 = -1.5\ ms^{-1}$$

Ans: Recoil velocity of the pistol is -1.5ms^{-1}. Negative sign shows that the pistol moves in the opposite direction of bullet.

2

From a rifle of mass 4 kg, a bullet of mass 50 g is fired with an initial velocity of 35 ms^{-1}. Calculate the recoil velocity of the rifle.



2

From a rifle of mass 4 kg, a bullet of mass 50 g is fired with an initial velocity of 35 ms^{-1}. Calculate the recoil velocity of the rifle.

Given : $m_2 = 4$ kg, $m_1 = 50$ g $= \frac{50}{1000} = 0.05$ kg

$u_1 = 0$ ms^{-1} $u_2 = 0$ ms^{-1}

$v_1 = 35$ ms^{-1}

To Find: $v_2 = ?$

Formula: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Solution: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$$\therefore (0.05 \times 0) + (4 \times 0) = (0.05 \times 35) + (4 \times v_2)$$

$$\therefore 0 = 1.75 + 4v_2$$

$$\therefore -4v_2 = 1.75$$

$$\therefore v_2 = \frac{-1.75}{4}$$

$$\therefore v_2 = -0.4375 \text{ ms}^{-1}$$

Ans:

The rifle recoils with a velocity of 0.4375 ms^{-1}. The negative sign indicates that the rifle recoils backwards.

LAWS OF MOTION

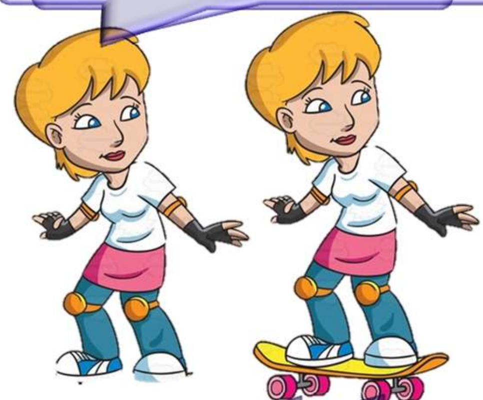
- Type C - Numericals

3

A girl of mass 40 kg jumps with a horizontal velocity of 5 ms^{-1} onto a stationary cart with frictionless wheels. The mass of the cart is 3 kg. What is her velocity as the cart starts moving ? Assume that there is no external unbalanced force working in the horizontal direction.

Initial Velocity(u_1) = 5ms^{-1}

Mass (m_1) = 40kg



Mass (m_2) = 3kg

Initial Velocity(u_2) = 0ms^{-1}

Final Velocity (v) = ?

3

A girl of mass 40 kg jumps with a horizontal velocity of 5 ms^{-1} onto a stationary cart with frictionless wheels. The mass of the cart is 3 kg. What is her velocity as the cart starts moving ? Assume that there is no external unbalanced force working in the horizontal direction.

Given :

Mass of the girl (m_1) = 40 kg

Mass of the cart (m_2) = 3 kg

Initial velocity of girl (u_1) = 5 ms^{-1}

Initial velocity of cart (u_2) = 0 ms^{-1}

To find : Final velocity of girl (v) = ?

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

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

$$40 \times 5 + 3 \times 0 = 40v + 3v$$

$$200 = 43v$$

$$v = \frac{200}{43} = 4.65\ ms^{-1}$$

Ans: Her velocity as the cart starts moving is 4.65 ms^{-1}.

4

An object of mass 1 kg travelling in a straight line with a velocity of 10 m s^{-1} collides with, and sticks to, a stationary wooden block of mass 5 kg. Then they both move off together in the same straight line. Calculate the total momentum just before the impact and just after the impact. Also, calculate the velocity of the combined object.

Given :

Mass of Object m_1 = 1 kg

Mass of Wooden Block m_2 = 5 kg

Initial Velocity of the object u_1 = 10 ms^{-1}

Initial Velocity of the wooden Block u_2 = 0 ms^{-1}

To find : $v_1 = v_2 = v = ?$

Formula : $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Solution :

Total momentum before impact $= m_1u_1 + m_2u_2$

$= 1 \times 10 + 5 \times 0$

$=$ 10 kg ms^{-1}

Total momentum after impact = Total momentum before impact

$\therefore$ Total momentum after impact = 10 kg ms^{-1}.

Ans : city of the combined object:

Total momentum just after collision is 10 kg ms^{-1}. Total momentum just before impact is 10 kg ms^{-1}. Velocity of the combined object is 1.67 ms^{-1}.

$v = \frac{10}{6} = \frac{5}{3}$

v = 1.617 ms^{-1}

5

Two objects of masses 100g and 200g are moving along the same line and direction with velocities of 2 ms^{-1} and 1 ms^{-1}, respectively. They collide and after the collision, the first object moves at a velocity of 1.67 ms^{-1}. Determine the velocity of the second object.

Given:

Mass of First Object (m_1) = 100 g = 0.1 kg

Mass of Second Object (m_2) = 200 g = 0.2 kg

Initial Velocity of First Object(u_1) = 2 ms^{-1}

Initial Velocity of Second Object(u_2) = 1 ms^{-1}

Final Velocity of First Object(v_1) = 1.67 ms^{-1}

To Find: Velocity of Second Object (v_2) = ?

Formula:

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Solution:

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$\therefore (0.1 \times 2) + (0.2 \times 1) = (0.1 \times 1.67) + (0.2 \times v_2)$$

$$\therefore 0.4 = 0.167 + 0.2v_2$$

$$\therefore 0.2v_2 = 0.233$$

$$\therefore v_2 = \frac{0.233}{0.2} = 1.165ms^{-1}$$

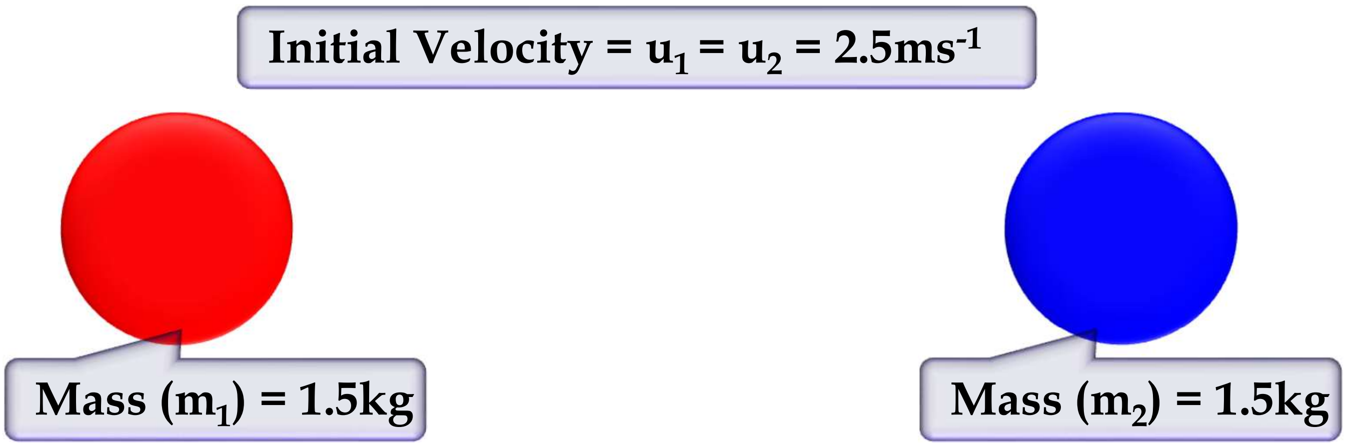
Ans: Velocity of the second object is 1.165ms^{-1}

LAWS OF MOTION

- Type C - Numerical

6

Two objects, each of mass 1.5 kg, are moving in the same straight line but in opposite directions. The velocity of each object is $2.5 ms^{-1}$ before the collision during which they stick together. What will be the velocity of the combined object after collision?



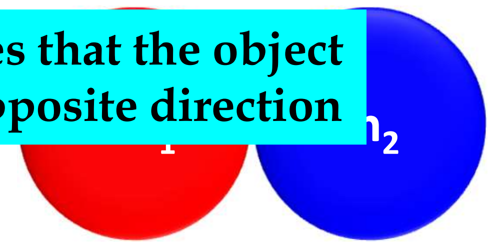
6

Two objects, each of mass 1.5kg, are moving in the same straight line but in opposite directions. The velocity of each object is $2.5 ms^{-1}$ before the collision during which they stick together. What will be the velocity of the combined object after collision?

Given: $m_1 = 1.5 kg$ $m_2 = 1.5 kg$

$u_1 = 2.5 m/s$ $u_2 = -2.5 m/s$

(-) sign indicates that the object is moving in opposite direction



To Find: $v_1 = v_2 = v$?

Formulae: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Solution: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$$\therefore (1.5 \times 2.5) + (1.5 \times -2.5) = (1.5 \times v) + (1.5 \times v)$$

$$\therefore 0 = 3v$$

$$\therefore v = 0 ms^{-1}$$

Ans: The velocity of the combined object after collision will be $0 ms^{-1}$.

7

Two hockey players of opposite teams, while trying to hit a hockey ball on the ground collide and immediately become entangled. One has a mass of 60kg and was moving faster with a velocity of 5ms^{-1} while the other has a mass of 55kg was moving faster with a velocity 6ms^{-1} towards the first player. In which direction and with what velocity will they move after they become entangled? Assume that the frictional force acting between the feet of the two players and the ... ligible.

(+) towards right

(-) towards left

Given: m_1 = 60k... m_2 = 55k...

$u_1 = +5ms^{-1}$ $u_2 = -6ms^{-1}$

To Find: Direction and Velocity after entangling

Formula: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Solution: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$\therefore (60 \times 5) + (55 \times 6) = (60 \times v) + (55 \times v)$

$\therefore 300 + (-330) = v\,(60 + 55)$

$\therefore -30 = 115v$

$$v = \frac{-30}{115}$$

$v = -0.26\ ms^{-1}$

Ans:

The two entangled players will move towards the left i.e. in the direction of 2nd Player with a velocity of 0.26ms^{-1}

State the law of conservation of momentum. Prove this law by taking the case of collision of two bodies.

Or

State the law of conservation of momentum. Write the equation describing the principal.

Ans : **<u>Law of conservation of momentum</u>.** This law states that if a number of bodies are interacting with each other (i.e., exerting forces on each other), their total momentum remains conserved before and after the interaction, provided there is no external force acting on them.

<u>Derivation from Newton's second law of motion</u>. Let p_1 and p_2 represent the sum of momenta of a group of objects before and after collision, respectively. Let t be the time elapsed during the collision.

According to Newton's second law of motion,

External force = Rate of change of momentum

$$F = \frac{p_2 - p_1}{t}$$

State the law of conservation of momentum. Prove this law by taking the case of collision of two bodies.

Or

State the law of conservation of momentum. Write the equation describing the principal.

Ans : Or

If there is no external force, that is F = 0, then

$$\frac{p_2 - p_1}{t} = 0$$

Or $$p_1 = p_2$$

Hence in the absence of an external force, the total momentum of a group of objects remains unchanged or conserved during the collision. This is the law of conservation of momentum.

An object experiences a net zero external unbalanced force. Is it possible for the object to be travelling with a non-zero velocity? If yes, state the conditions that must be placed on the magnitude and direction of the velocity. If no, provide a reason.

Ans : Yes, an object may travel with a non-zero velocity even when the net external force on it is zero. A rain drop falls down with a constant velocity. The weight of the drop is balanced by the upthrust and the viscosity of air. The net force on the drop is zero.