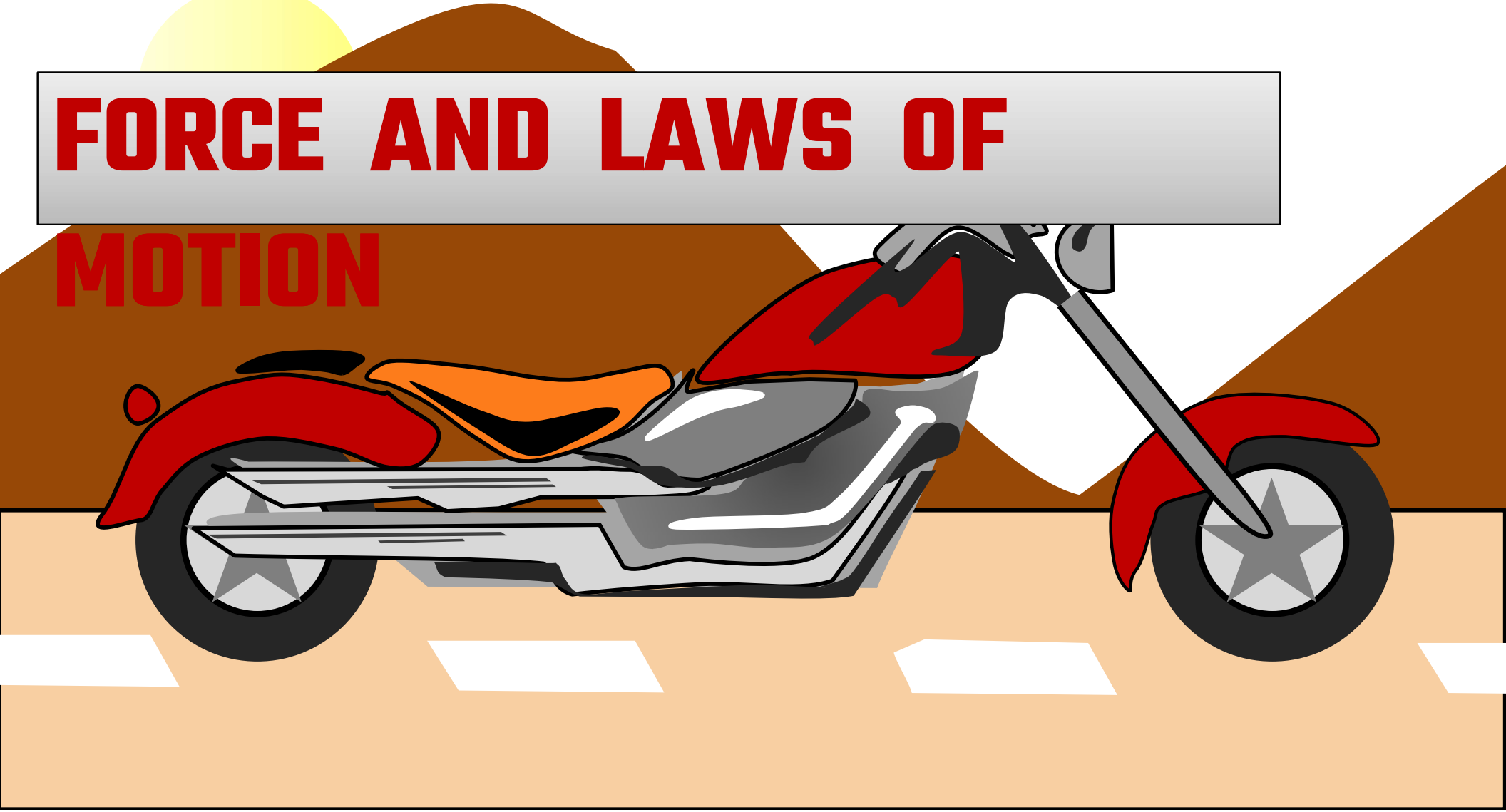
FORCE AND LAWS OF MOTION



FORCE AND LAWS OF MOTION

Means

Ru

Causes of motion is force

Object is in motion when It changes its Position with time

In the picture we can see people pushing the wagon

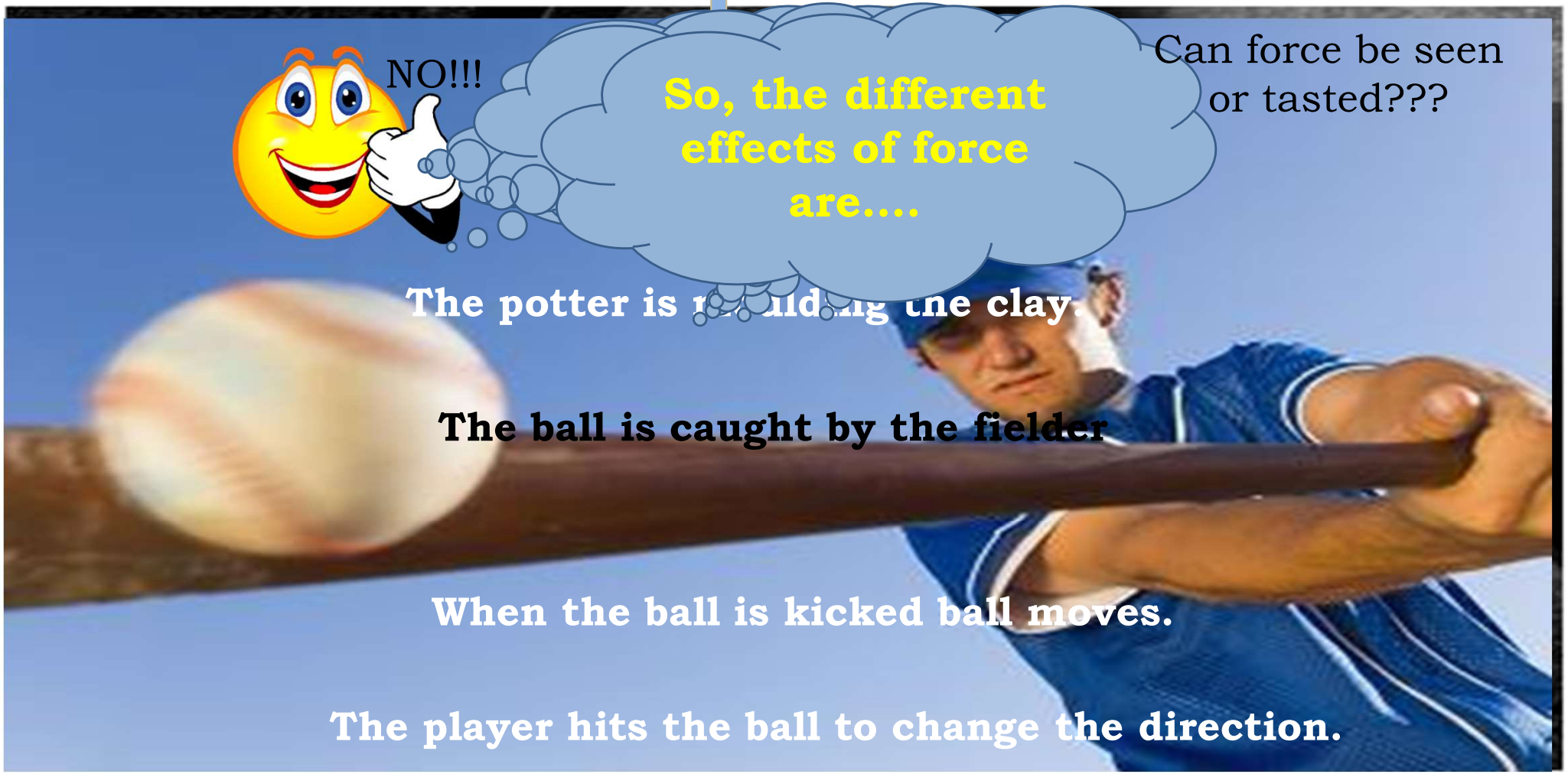
FORCE

Simple push or pull is FORCE!!

We can say that the car is being pulled by the tow van

Pull is **FORCE**

4. [illegible]TION EFFECTS OF FORCE EFFECTS OF FORCE



Are there different kinds

Yes....!!!!!!

ORCES

Are of two types

D FO

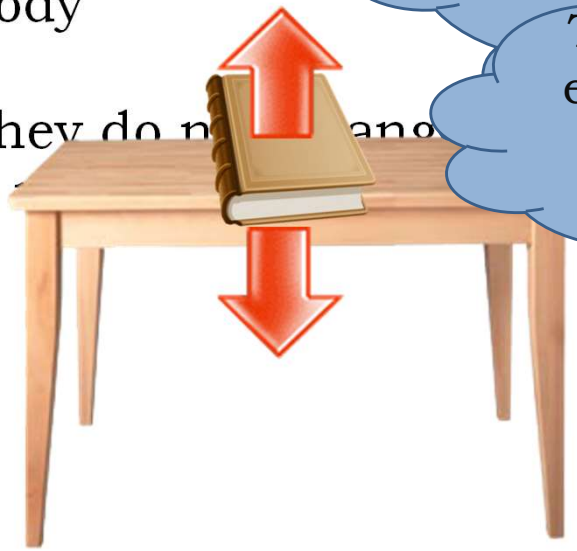
BALANCED FORCES

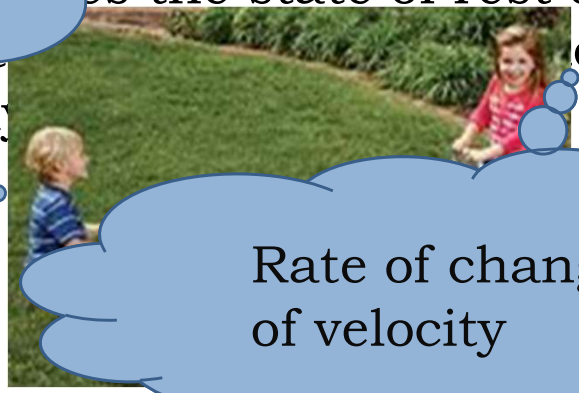
1. Forces which ar… …ich are unequal in magnitude an… …and acting on the same direction actin… body

2. They do n… …ang… …es the state of rest or of of … …on in a …body

…table is exerting an upward force on the book and the weight of the book is in the downward direction

The children are exerting unequal forces on the seesaw



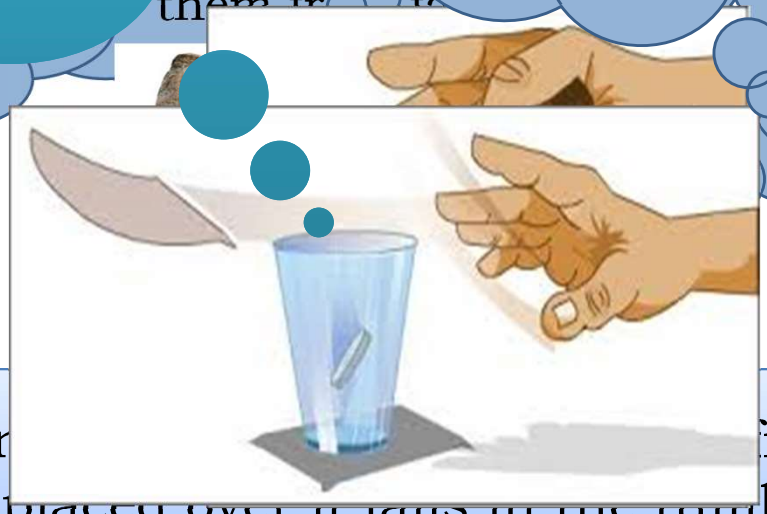


Rate of change of velocity

INERTIA

When the playing card is flicked the coin placed over it falls in the tumbler This is because the coin does not move with the card because of **Inertia**

Let us consider a card placed on a glass and a coin placed on the card.



ll and stone are of me size but have different masses. So stone will need greater force to bring about a change due to it greater inertia

Why..??

ist a change in its state

mass g… its inertia.

th… f… t…

Wher… …inger the coin placed over it falls in the tumbler

Newton's Laws of Motion

Means rules

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

These Laws are known as…..

NEWTON'S FIRST LAW OF MOTION

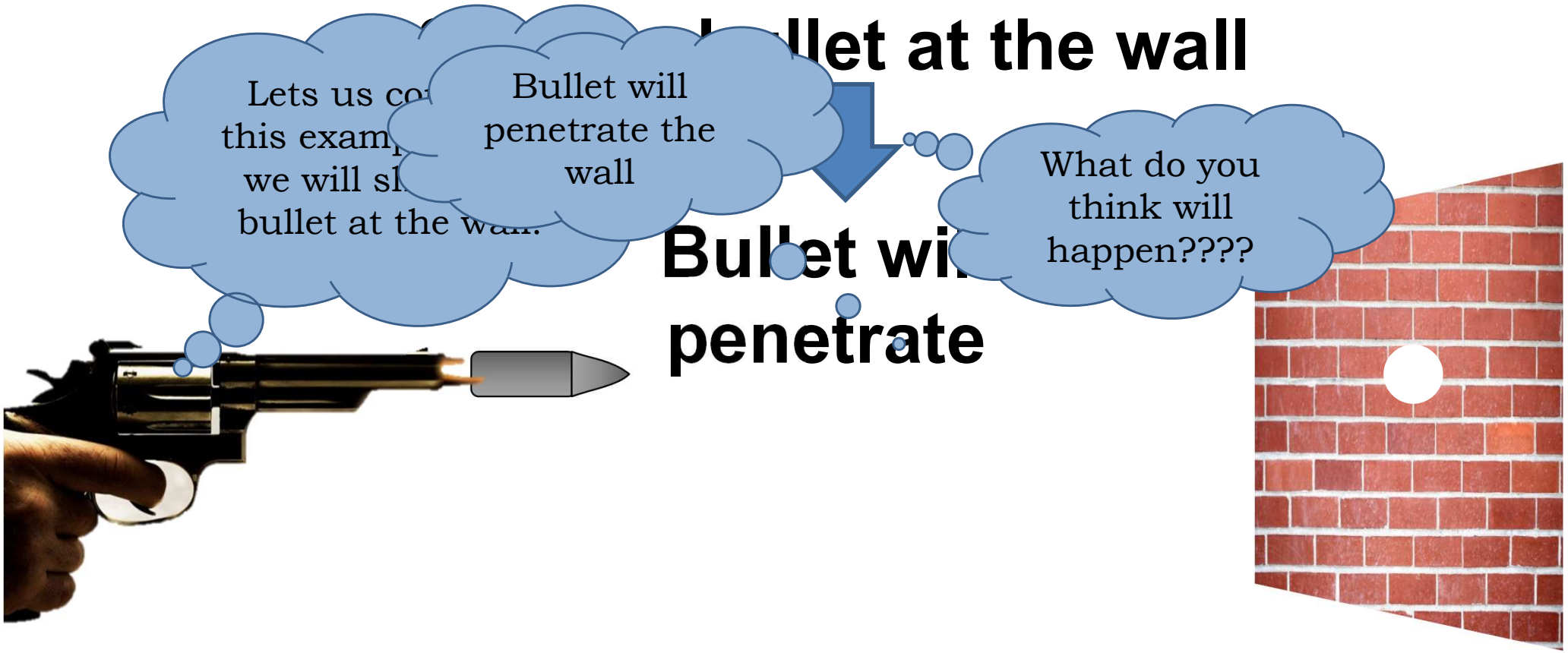
Forced to

Newton's fi[illegible]n is stated as:
An object remains in a state of rest or of uniform motion in a straight line unless compelled to Change that state by an applied force.

This is wh[illegible]his known as
"The Lav
Is
IMPL
but
The fi[illegible]unbalanced
All obj[illegible]motion
External
changes.

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

[illegible]is at rest
and will continue
to be at rest.


Lets us co
this exam
we will sl
bullet at the wall.
Bullet will penetrate the wall
What do you think will happen????
Bullet wi
penetrate

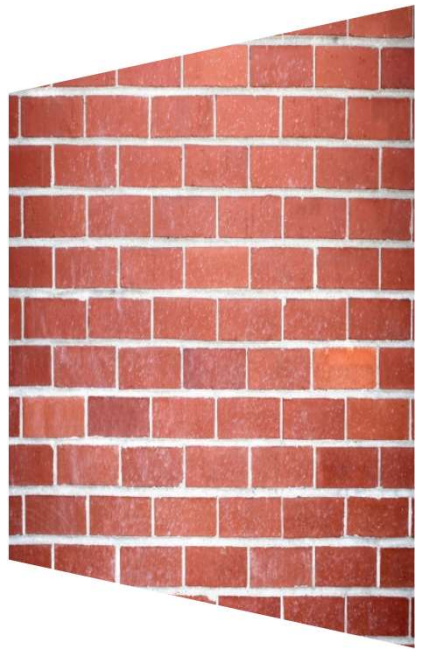
Throw a bullet (of same mass) on the wall

t will happen??

ll not penetrate!!!

Why??

Let us understand what is momentum????



MOMENTUM (p)

Momentum(p) of an object is defined as product of its mass (m) and velocity (v)

$$\text{Momentum} = \text{mass} \times \text{velocity}$$

$$p = m \times v$$

$$p = mv$$

Needs both magnitude & direction

Momentum is a vector quantity

UNIT

SI / MKS $p = kg \times ms^{-1}$

CGS $p =$

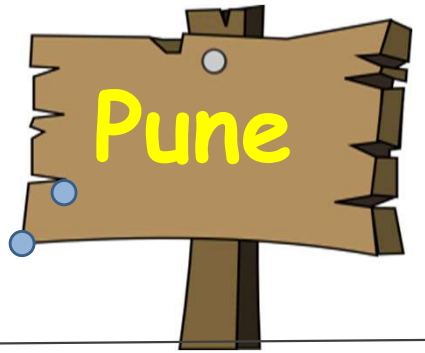
Newton's Second Law of Motion

momentum is changed.

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.

The change in the momentum depends on not only the force applied but also the time duration

If one quantity increases the other quantity also increases accordingly.



MATHEMATICAL FORMULATION OF SECOND LAW OF MOTION

$p_2 = mv$

With respect to time

mass x initial velocity

mass x final velocity

Final - initial

According to second law

'k' is the proportionality

'a' is the acceleration i.e. rate of change of velocity.

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

$F = k\frac{mv - mu}{t}$

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

If $k = 1$, Then

$F = ma$

State the first law of motion mathematically from the mathematical expression for the second law of motion.

Mathematical expression for Newton's second law of motion is :

$$F = ma$$

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

$$\text{or} \quad Ft = mv - mu$$

when $F = 0$

Then $v = u$

If $u = 0$ then $v = 0$

This is nothing but the first law of motion.

when external force

This means that object is moving with uniform velocity throughout time (t).

Thus the first law of motion is stated mathematically from second law of motion.

A force is that physical cause which changes (or tends to change) either the size or shape or the state of rest or motion of the body.

- **Force is a VECTOR quantity**

a is acceleration

Needs both magnitude and direction.

$F = ma$

$kg\ m\ s^{-2}$

units

SI/MKS	CGS
Newton (N)	**dyne**

Relation between SI unit & CGS unit of Force

SI unit of Force

$$F = ma$$

1 m = 100cm.

1 newton = 1kg × 1 ms^{-2}

1 N = 10^3g × 10^2 cms^{-2}

∴ 1 N = 10^5g cms^{-2}

1 g cms^{-2} is nothing but 1 dyne.

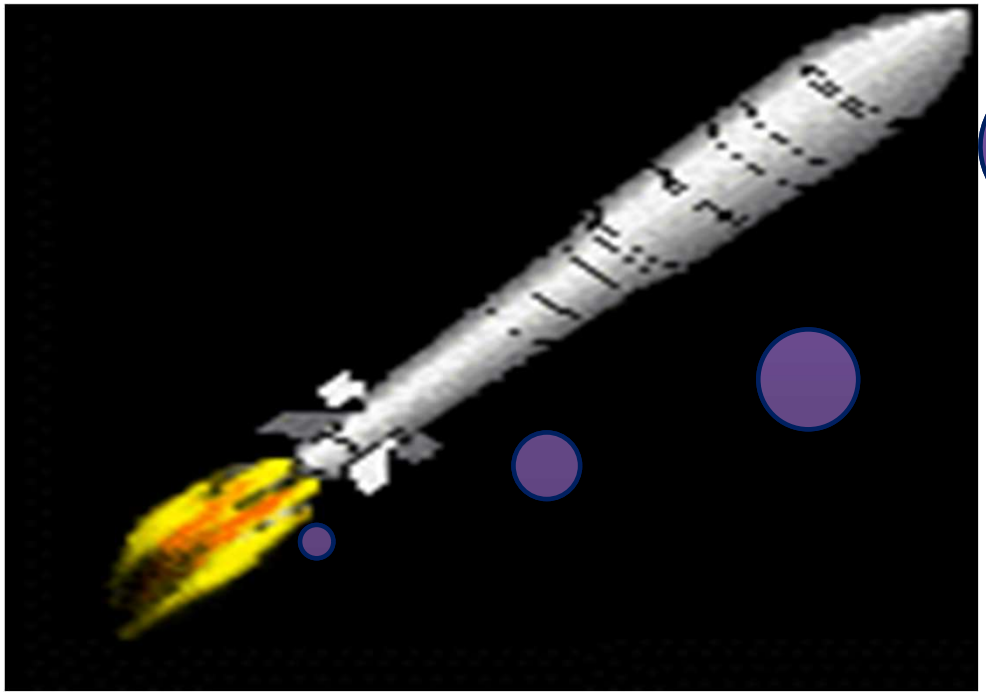
∴ 1 N = 10^5 dyne

∴ 1 N = 10^5 dyne

Newton's third law of motion:

The third law of motion states that when one object exerts a force on another object, the second object instantaneously exerts a force back on the first.

These two forces are equal in magnitude but opposite in direction.



The rocket exerts a downward force on the gases. The gases in turn exerts an equal and opposite force which will propel the rocket in to the space.

The Law speaks about :

- **Interaction betw**
- **Force is neve** **t in pairs.**
- **Force, though they are equal and opposite, they never cancel each other.**

If the forces are equal and opposite they should cancel each other.

oy and oline.

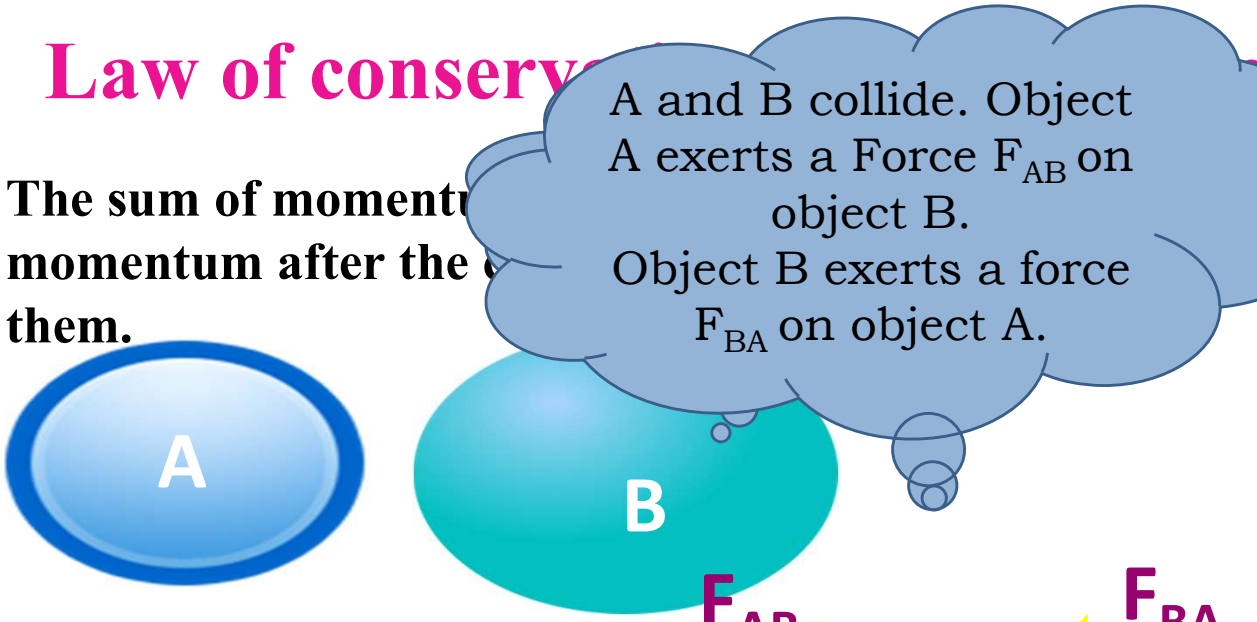
trampoline exert an equal force

For every action there is

As the forces act on different bodies (boy and the trampoline) they do not cancel each other.

Law of conserv

The sum of momentu **equal to the sum of momentum after the** **unbalanced force acting on them.**



	object A		object B
mass ➡	m_A		m_B
Initial velocity ➡	u_A	$u_A > u_B$	u_B
Final velocity ➡	v_A		v_B

Law of conservation of momentum:

Momentum of object A — Momentum of object B

Before collision $m_A\ u_A$ — Before collision $m_B\ u_B$

After collision — collision $m_B\ v_B$

During coll…

Rate of ch… A = $\dfrac{m_A\ (v_A - u}{t}$

Rate of change … of object B = $\dfrac{m_B\ (v_B - u_B)}{t}$

According to t…rd law of motion

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

$\dfrac{m_A\ (v_A - u_A)}{t}$

This gives ,

$$m_A\ u_A + m_B\ u_B = m_A\ v_A + m_B\ v_B$$

Thus, The total momentum of the two objects remains **unchanged** or **conserved** provided **no** external force acts.

For every action there is an equal and opposite reaction.

't' is time of collision

't' is time of collision

Sum of the initial momentum of the two object A & B

Sum of the final momentum of the two object A & B

LAWS OF MOTION

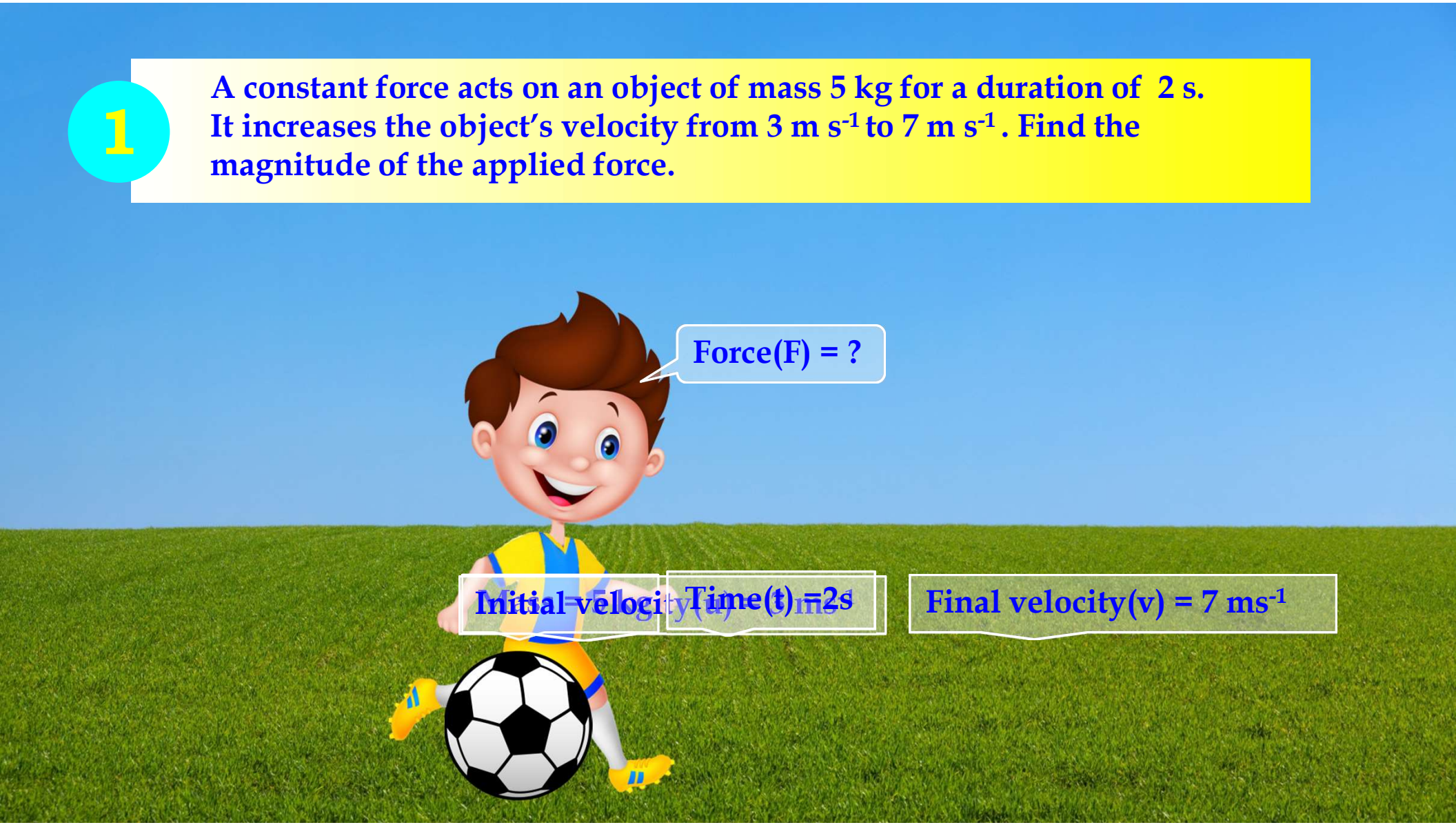
- **Type A - Numerical**

Type - A

$$F = ma$$

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

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

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 2 kg mass at $5ms^{-2}$ or a 4 kg mass at $2ms^{-2}$?

Given :

Mass of 1st object (m_1) = 2 kg

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

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

Acceleration of the 2nd 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 1200 kg at a uniform velocity along a level road. The same motorcar can be pushed by three persons to produce an acceleration of 0.2 ms^{-2}. With what force does each person push the motorcar?
(Assume that all persons push the motorcar with the same muscular effort.)

Given : $m = 1200\ kg$
$a = 0.2\ m\ s^{-2}$

Ans : Each person applies a force of magnitude 80 N

To find : $F = ?$

Formula : $F = ma$

Solution : $F = ma$

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

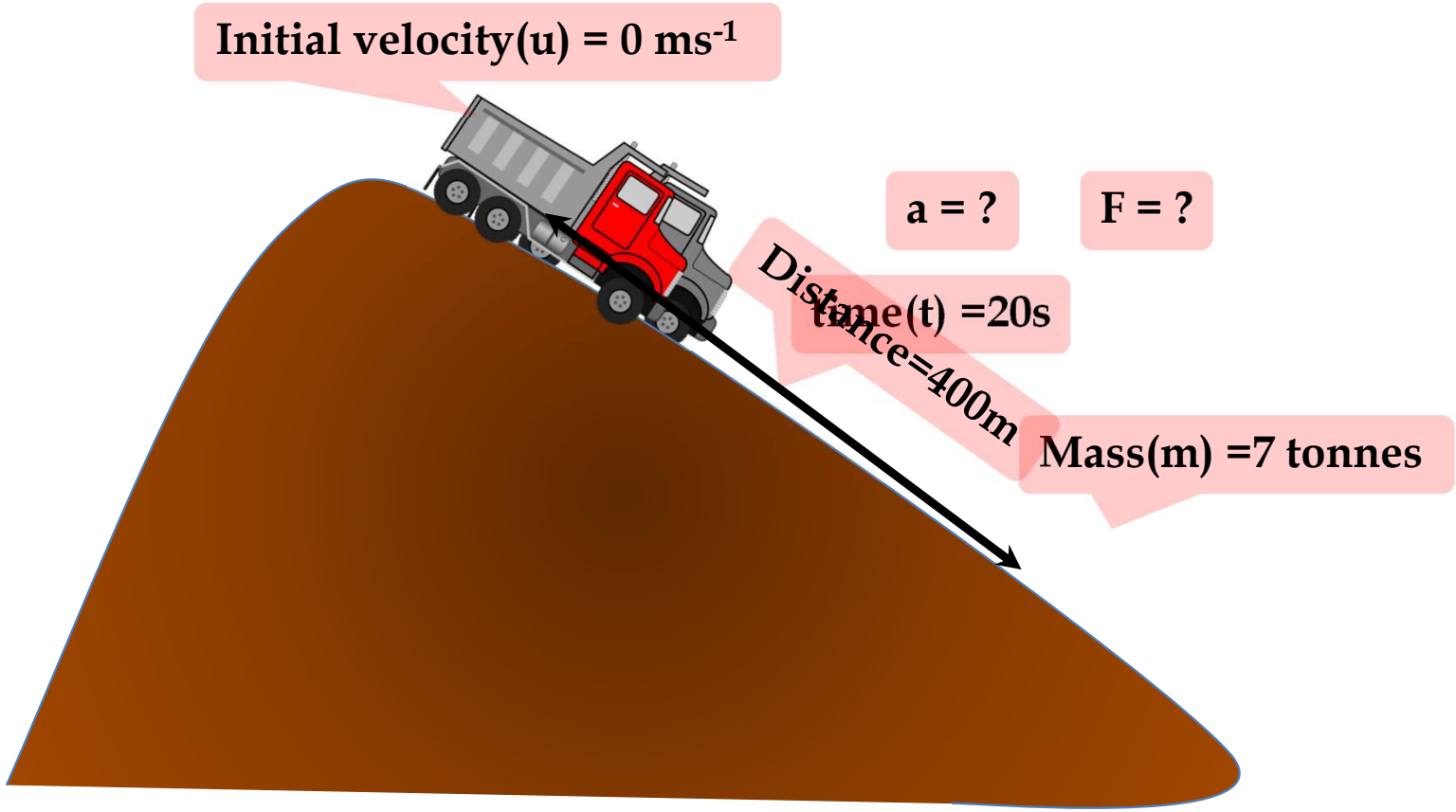
$\therefore \quad F = 240\ N$

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

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) = 400m

Time (t) = 20s

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) $F = ma$

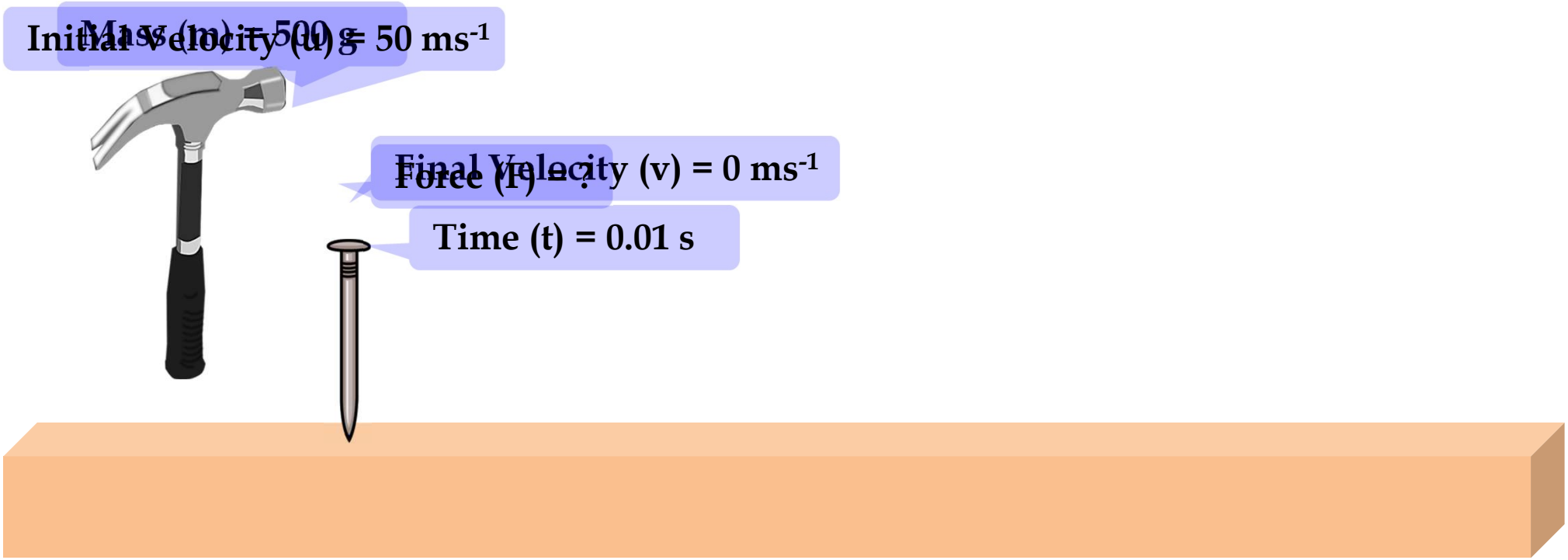
$\therefore \quad F = 7000 \times 2$

$\therefore \quad F = 14000N$

Ans :

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

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

$= 0.5\ kg$

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

$t = 0.01\ s$

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

To Find : $F = ?$

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

(ii) $F = ma$

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

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

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

$F = ma$

$\therefore F = 0.5 \times -5000$

$\therefore F = -2500N$

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.

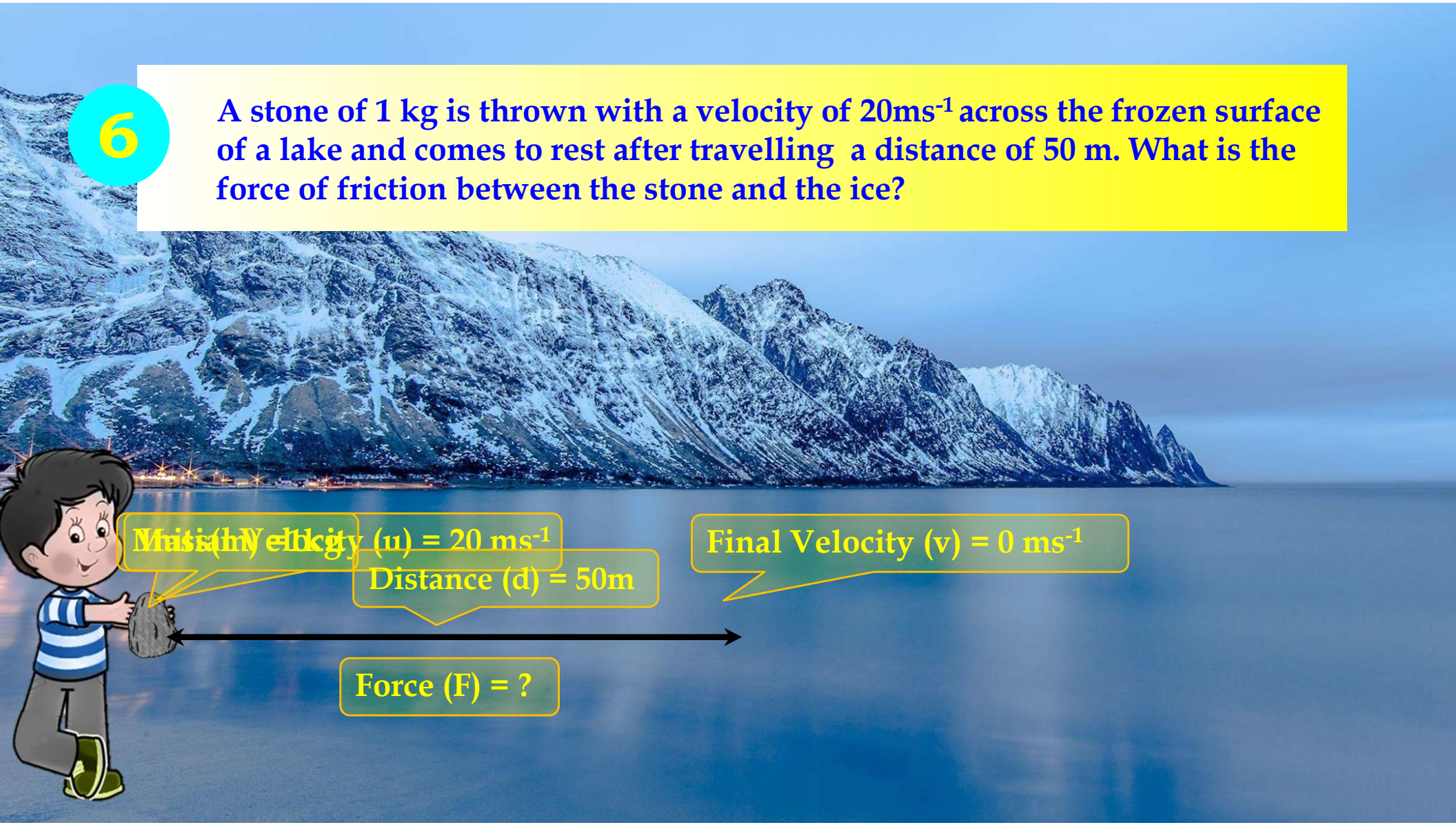
LAWS OF MOTION

- **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 $20ms^{-1}$ 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 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) $v^2 = u^2 + 2as$

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

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

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

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

(ii) $F = ma$

$\therefore F = 1 \times -4$

$\therefore F = -4N$

Ans:

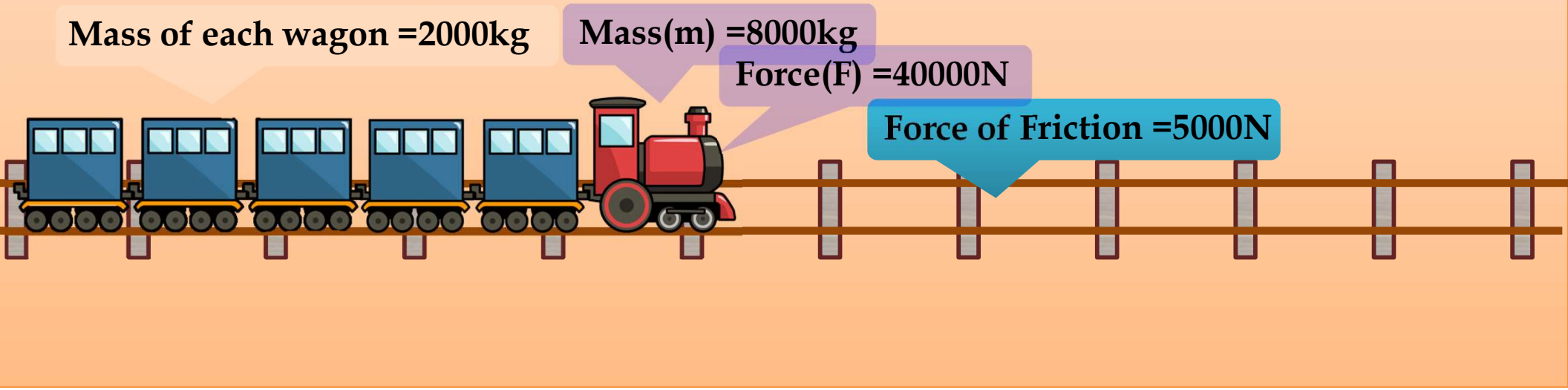
Force of friction between ice and stone is -4N

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

LAWS OF MOTION

- **Type A - Numericals**

7 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.



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

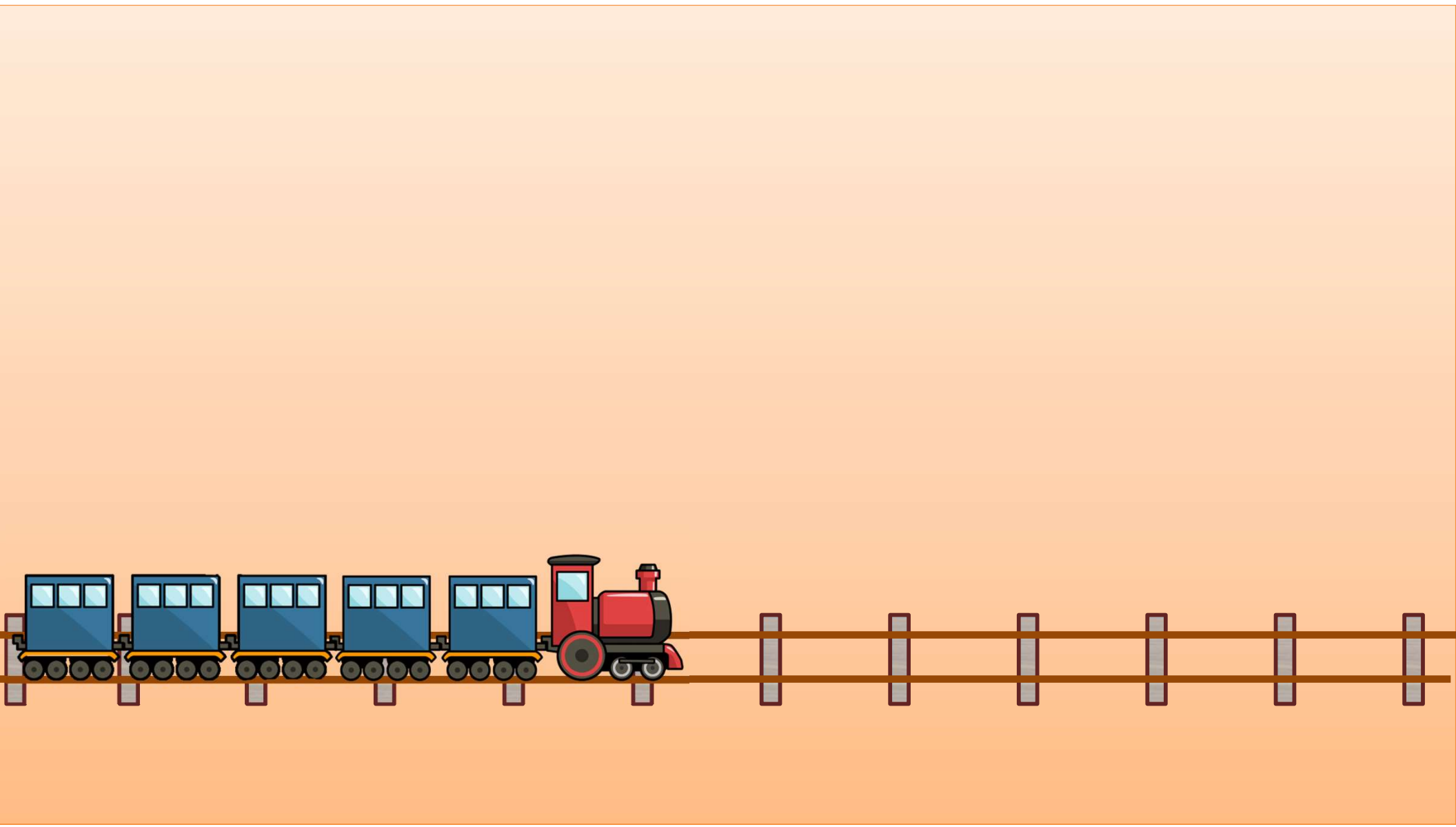
Total Mass = 8000 + 5(2000)

= 8000 + 10000

$= \frac{F}{m}$

$\frac{35000}{18000} = 1.94\ ms^{-2}$

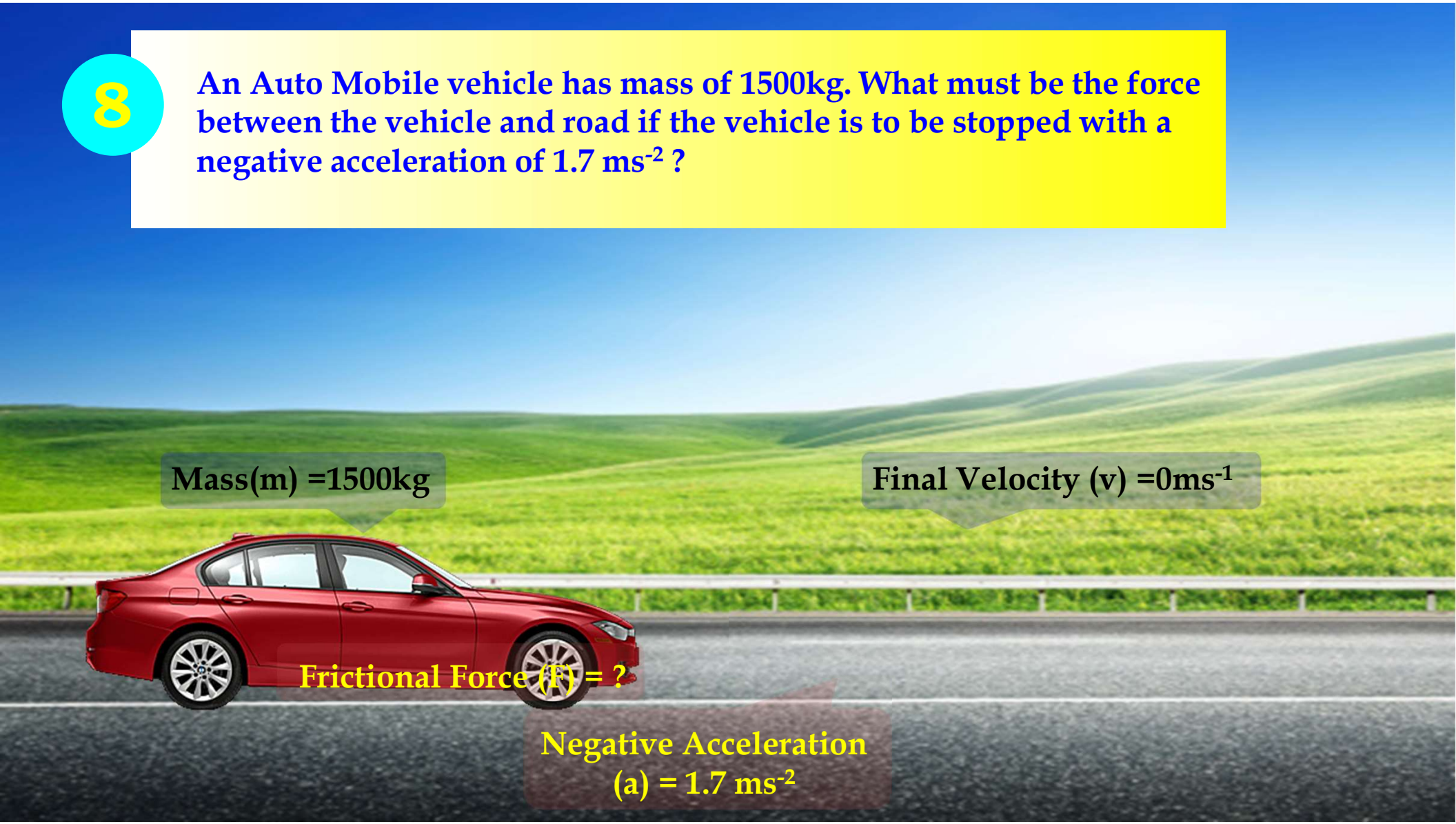
(c) Force of Wagon 1 on Wagon 2 = Mass of 4 wagons behind wagon 1 × a



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

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

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

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

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

$F = 5\ N$

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 $= 0.5 + 0.25 = 0.75kg$

$F = ma$

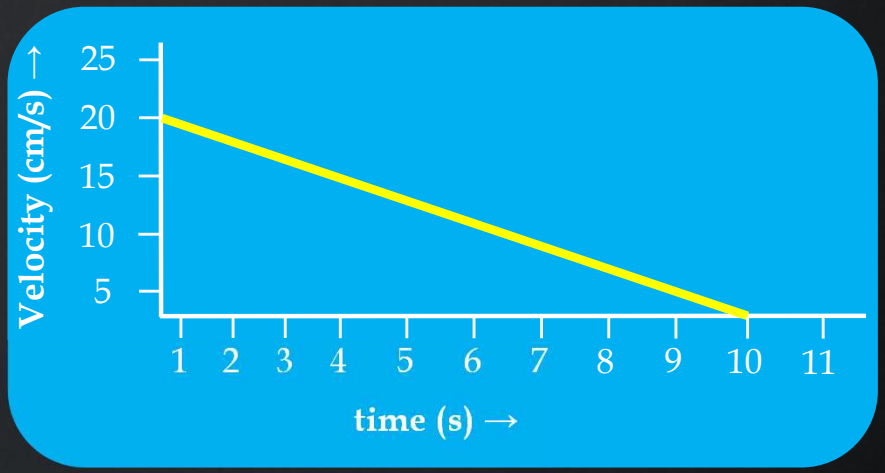
$$a = \frac{F}{m} = \frac{5}{0.75} = 6.67\ ms^{-2}$$

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?**



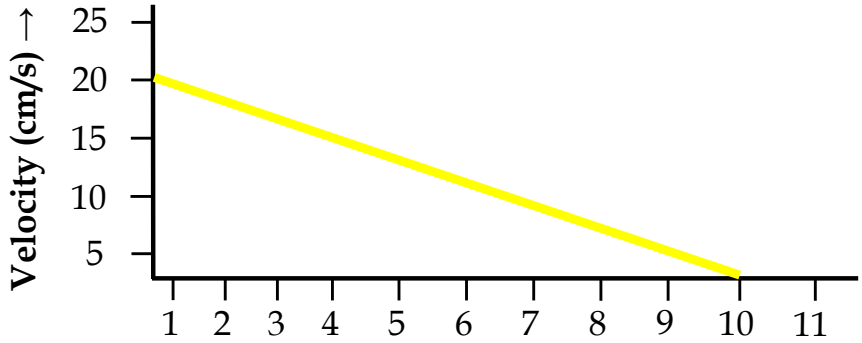
Force of Friction (F) = ?

Mass(m) =20g

Initial Velocity (u) =20cms^{-1}

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

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?



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

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

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

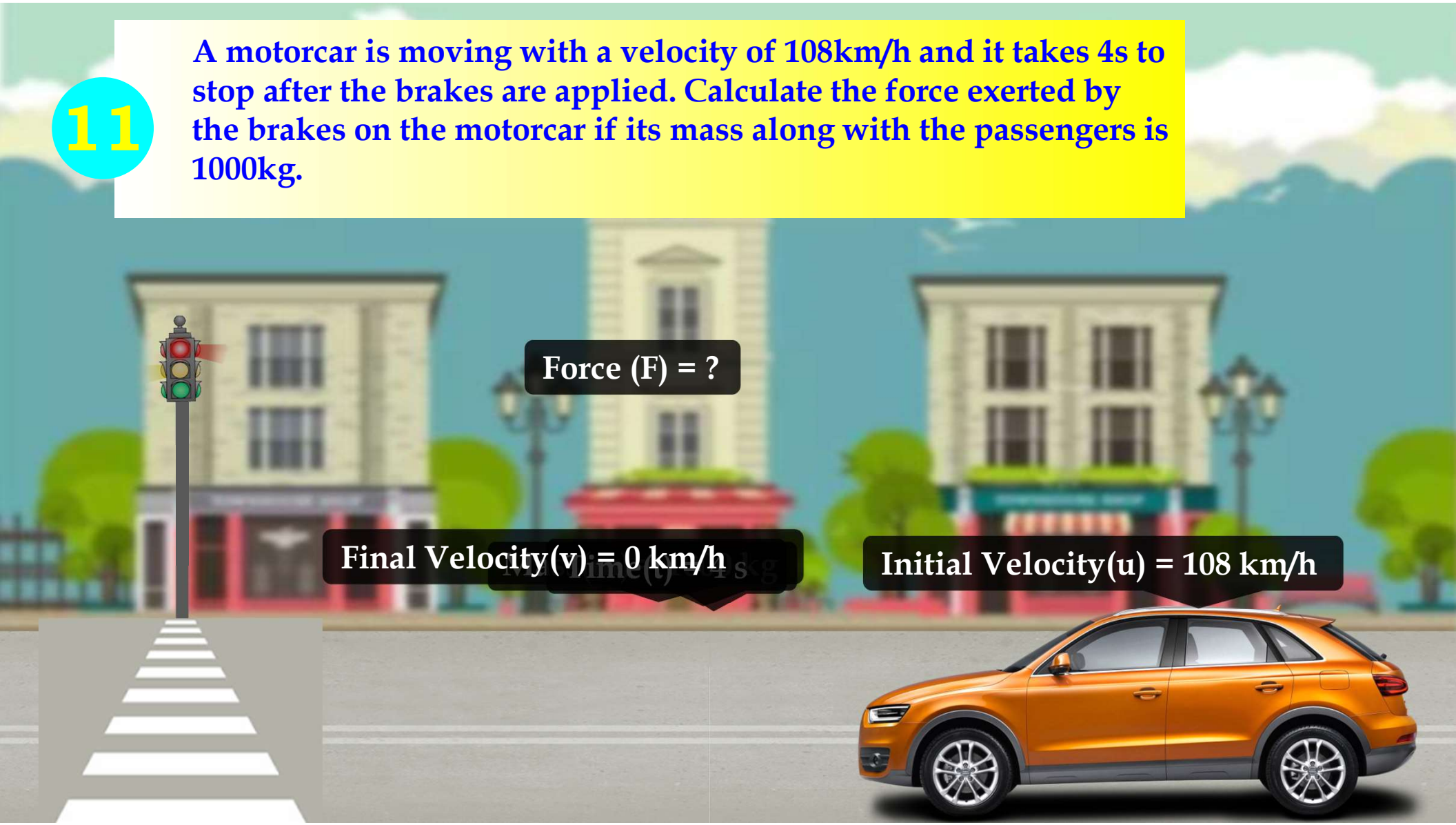
$F = m\,a$

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

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 :

$u = 108\text{km/h} = 108 \times \frac{1000}{60 \times 60} = 30\ \text{ms}^{-1}$

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

$t = 4\text{s}$

$m = 1000\text{kg}$

To Find: $F = ?$

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

Solution:

$a = \frac{v$

The –ve sign shows that the body is retarding

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

$F = ma$

$F = 1000 \times -7.5$

$F = -7500\ \text{N}$

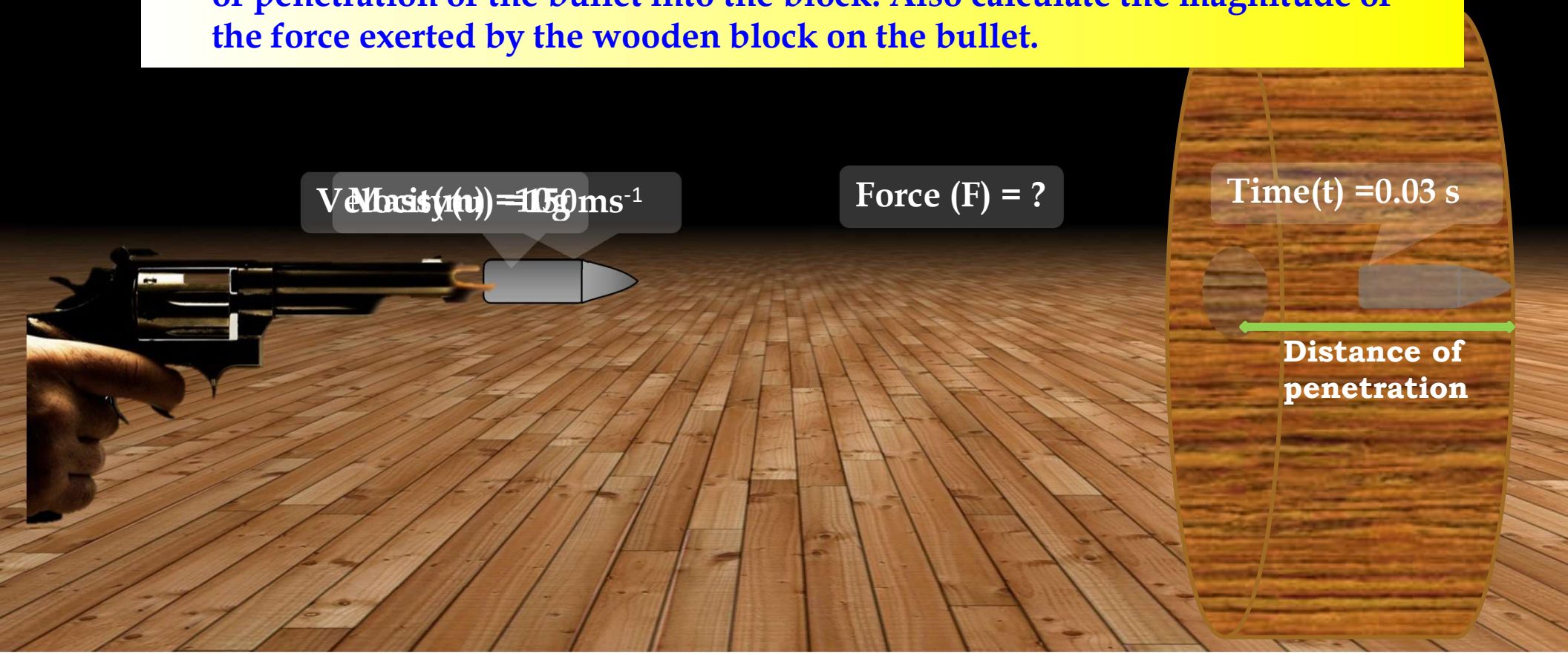
Ans:

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 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.

Given :

mass (m) = 10 g = 0.010 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:

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

$0.03\,a = -150$

$a = \frac{-150}{0.03} = \frac{-15000}{3} = -5000\ ms^{-2}$

-ve Sign shows that it is retardation

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

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

$2as = 0 - u^2$

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

Distance of penetrat

-ve Sign shows that it is Force of Friction

$F = ma$

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

LAWS OF MOTION

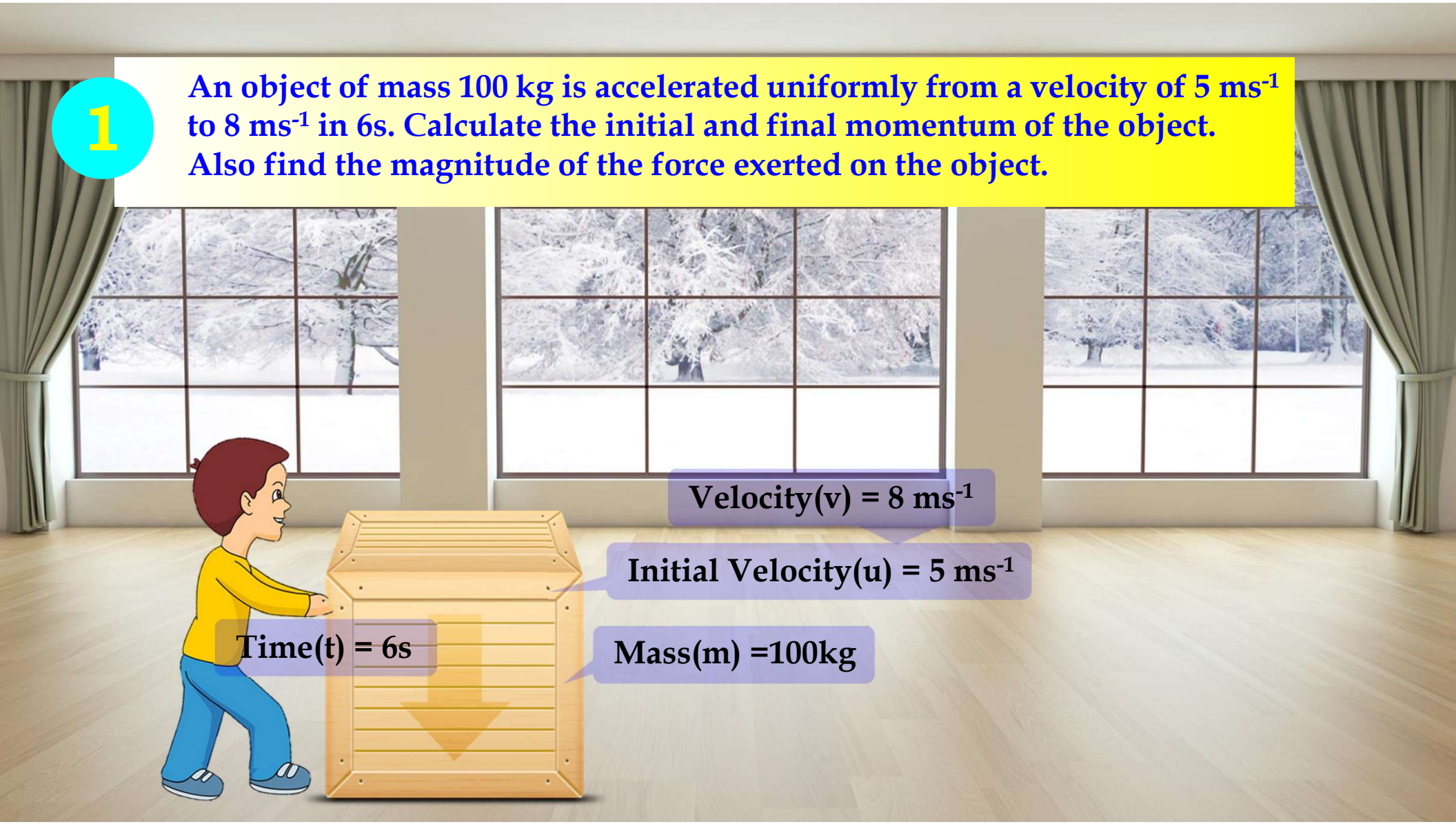
- **Type B - Numerical**

Type - B

$p = mv$

$\Delta p = mv - mu$

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 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.

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

Solution:

(a) Initial momentum (p_1) = mu

= 100 × 5 = 500 kg ms^{-1}

(b) Final momentum (p_2) = mv

= 100 × 8 = 800 kg ms^{-1}

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

$\therefore a = \frac{8-5}{6}$

$\therefore a = \frac{\cancel{3}^{1}}{\cancel{6}_{2}}$

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

$F = ma$

$\therefore F = 100 \times 0.5$

$\therefore F = 50$ 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: $m = 200g = \frac{200}{1000} = 0.2\ kg$

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

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

To Find: Change of momentum (Δp) = ?

Formulae: $\Delta p = mv - mu$

Solution: $\Delta p = mv - mu$

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

$\Delta p = -1 - 2$

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

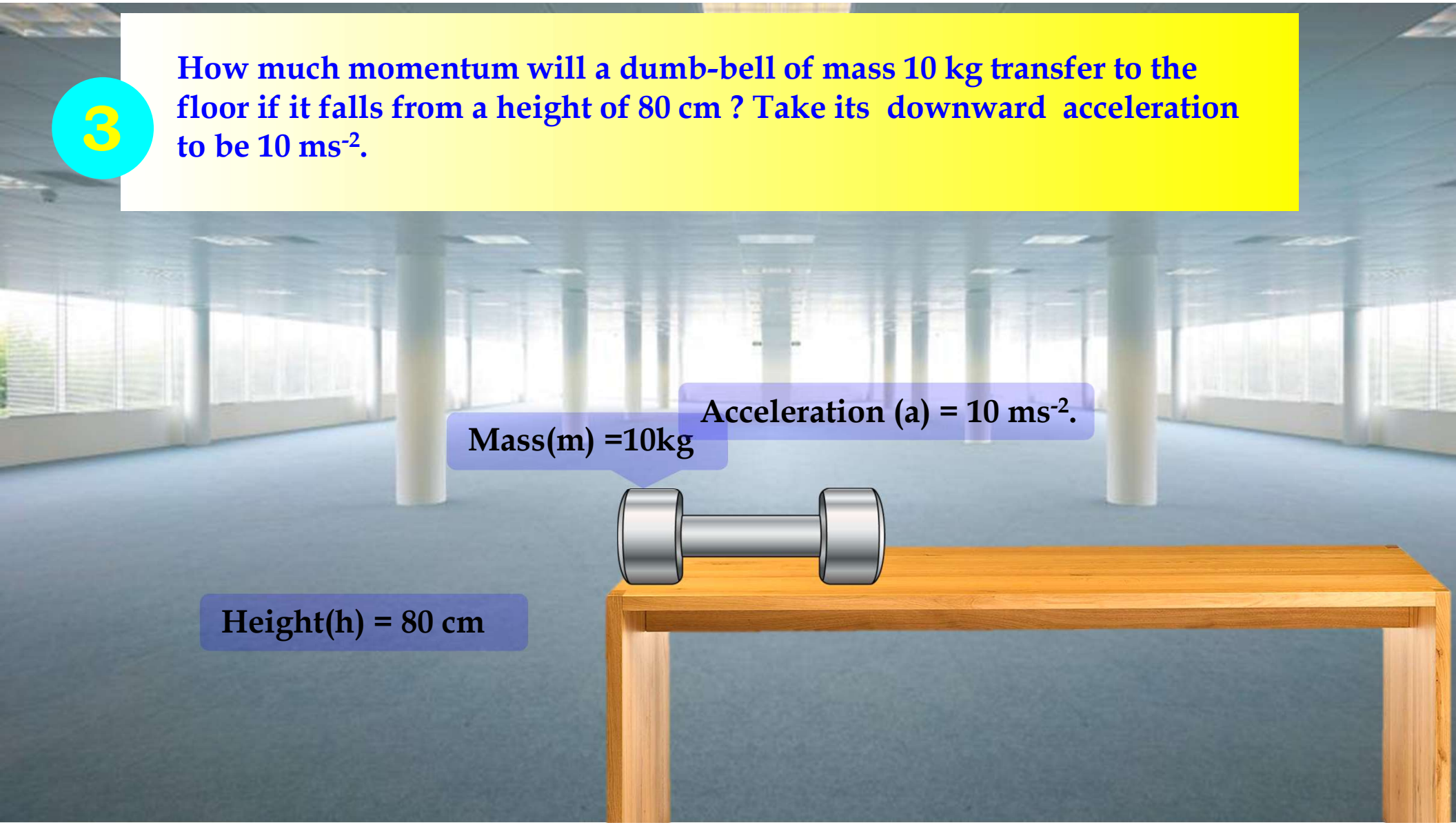
The negative sign indicates that the object is moving in opposite direction

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

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 10 kg transfer to the floor if it falls from a height of 80 cm? Take its downward acceleration to be 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 :

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

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

$v^2 = 16$

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

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

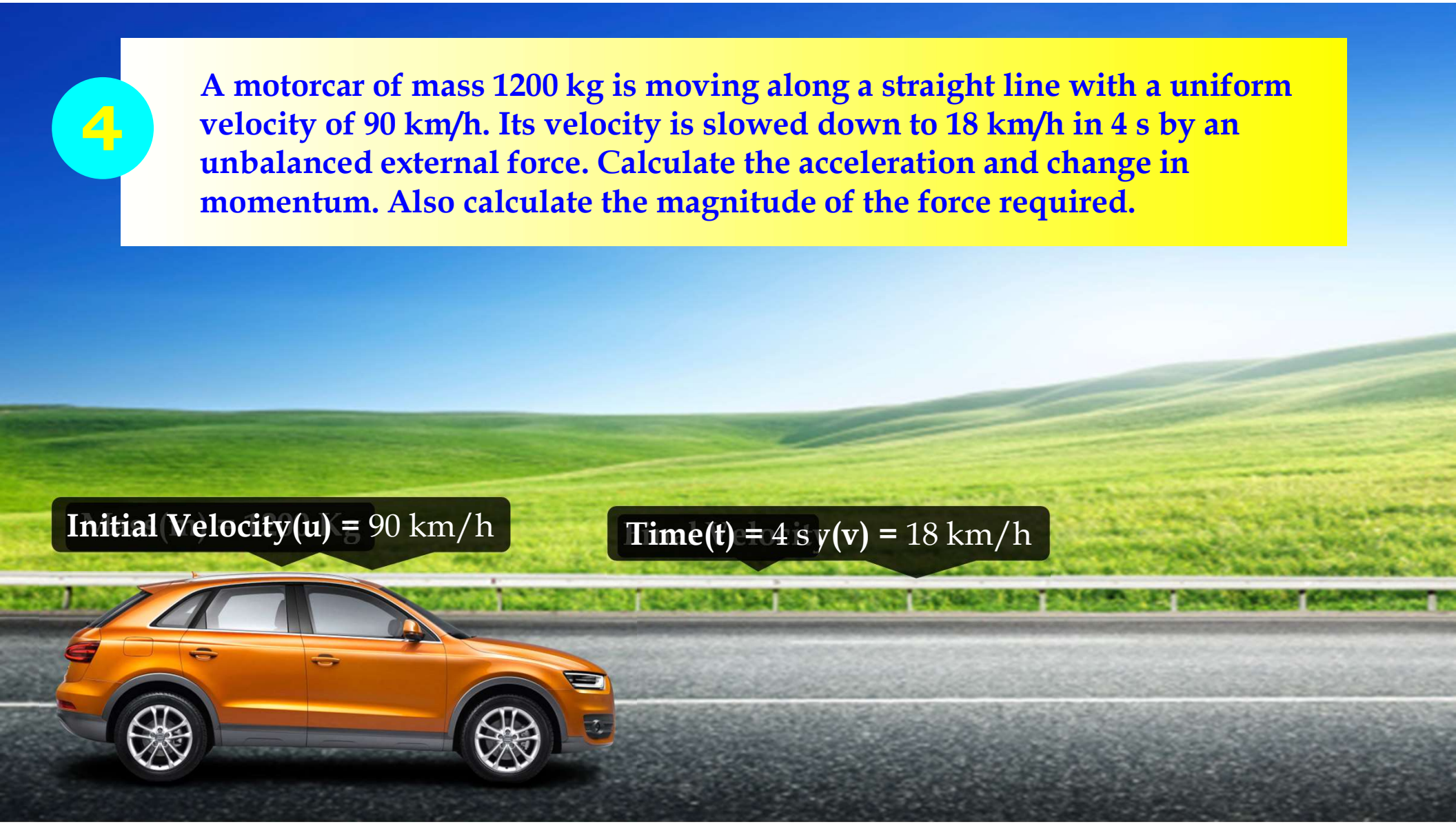
$p = mv$

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

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

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 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.

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 $5ms^{-2}$ and the change in momentum is $24000kgms^{-1}$. 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

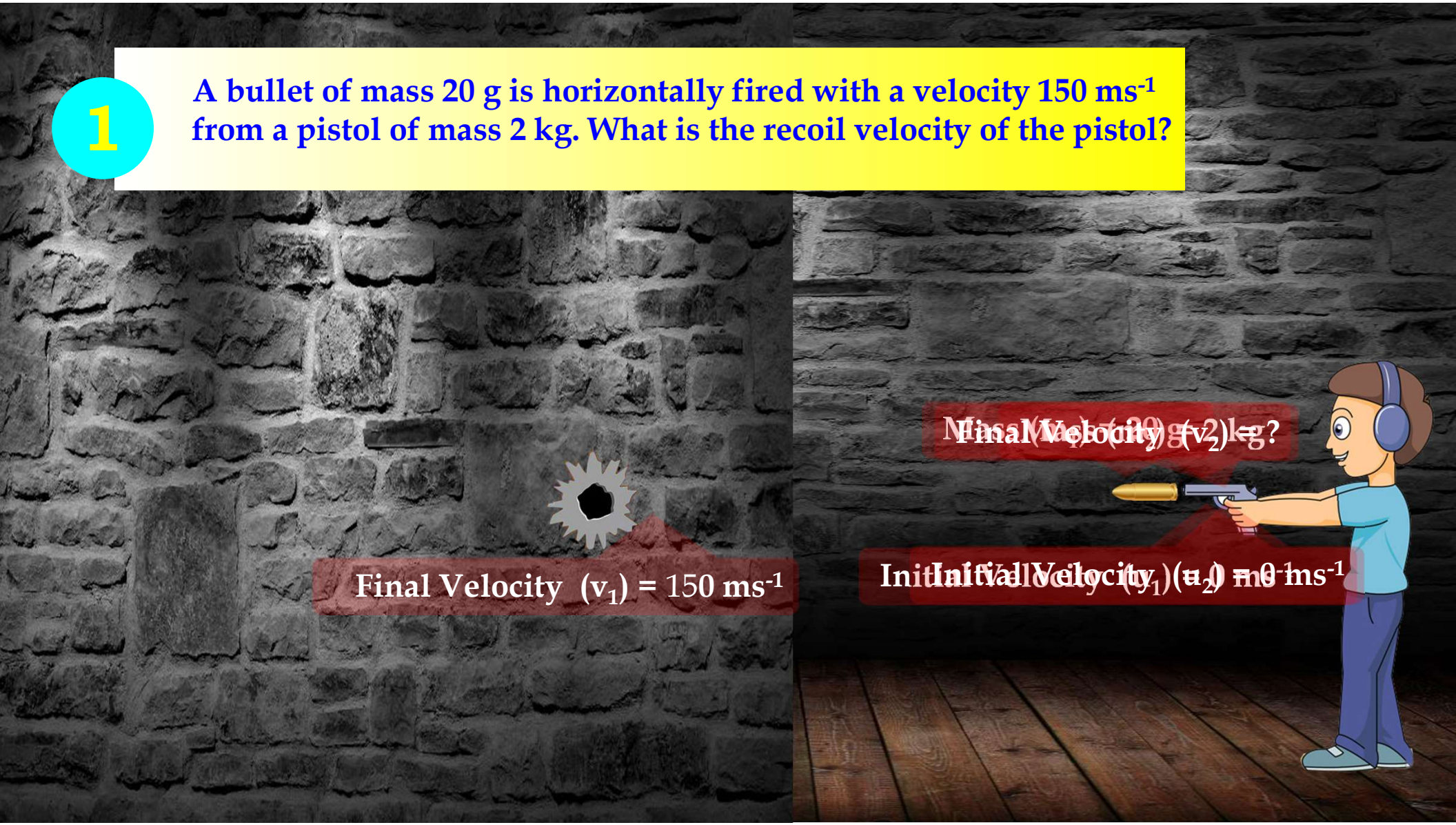
m = Mass of the body

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:

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

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

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

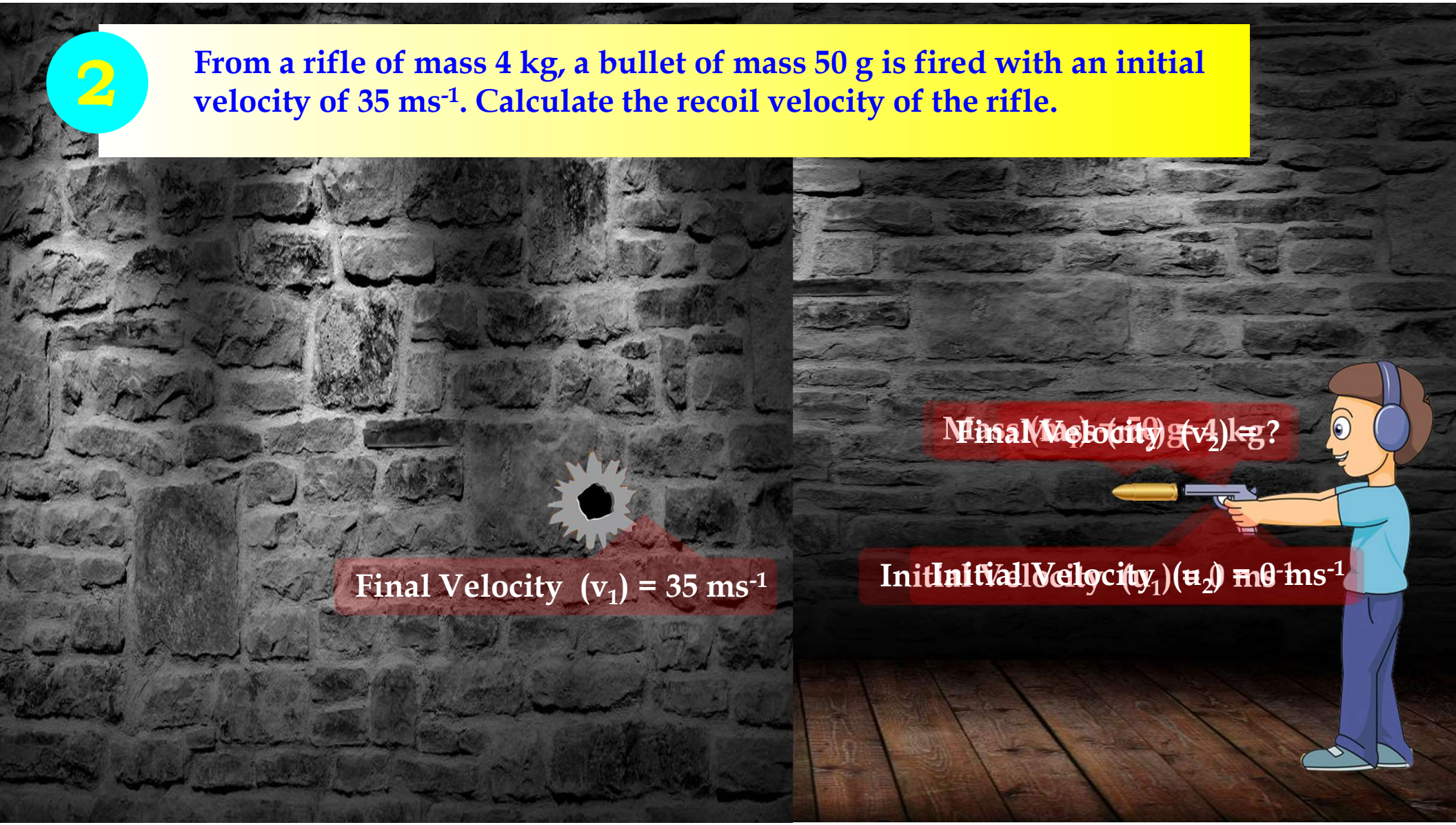
$$2 v_2 = -3$$

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

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

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

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

$v_1 = 35ms^{-1}$

To Find: $v_2 = ?$

Formula: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Solution: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

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

$\therefore 0 = 1.75 + 4v_2$

$\therefore -4v_2 = 1.75$

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

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

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.

Mass (m_1) = 40kg

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

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

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

$200 = 43v$

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

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 : ity 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}.

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

$$v = 1.617 \text{ ms}^{-1}$$

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:

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

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

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

$$\therefore 0.2v_2 = 0.233$$

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

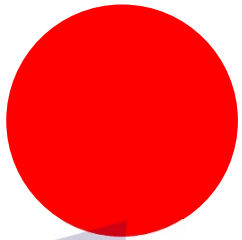
Ans: Velocity of the second object is 1.165 ms^{-1}

LAWS OF MOTION

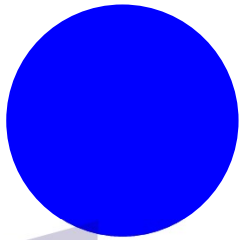
- **Type C - Numerical**

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 $2.5ms^{-1}$ before the collision during which they stick together. What will be the velocity of the combined object after collision?

Initial Velocity = $u_1 = u_2 = 2.5ms^{-1}$



Mass (m_1) = 1.5kg



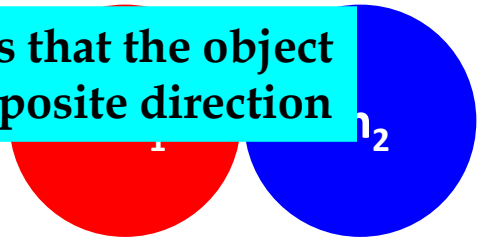
Mass (m_2) = 1.5kg

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 $2.5ms^{-1}$ before the collision during which they stick together. What will be the velocity of the combined object after collision?

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

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

(-) 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: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

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

$\therefore 0 = 3v$

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

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

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 [illegible]

(+) towards right

(-) towards left

Given: $m_1 = 60$ [illegible] $m_2 = 55$ [illegible]

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

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 $0.26ms^{-1}$