7^{TH} FOUNDATION PLUS NEWTON'S THIRD LAW OF MOTION

TEACHING TASK

1.

- Mass, $m = 150 \text{ gm} = 0.150 \text{ kg}$
- Acceleration, $a = -500 \text{ m/s}^2$

Substituting the values:

$$F = (0.150 \text{ kg}) \times (-500 \text{ m/s}^2) = -75 \text{ N}$$

Rearranging the equation to solve for distance (s):

$$s = \frac{v^2 - u^2}{2a}$$

Substituting the values:

$$s = \frac{(0 \text{ m/s})^2 - (20 \text{ m/s})^2}{2 \times (-500 \text{ m/s}^2)} = \frac{-400 \text{ m}^2/\text{s}^2}{-1000 \text{ m/s}^2} = 0.4 \text{ m}$$

- Initial velocity, $u = 20 \text{ m/s}$
- Final velocity, $v = 0 \text{ m/s}$
- Time, $t = 0.04 \text{ s}$

Rearranging the equation to solve for acceleration (a):

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

Substituting the values:

$$a = \frac{0 \text{ m/s} - 20 \text{ m/s}}{0.04 \text{ s}} = -500 \text{ m/s}^2$$

2.

- Mass (m) = 0.05 kg
- Initial velocity (v_i) = 4 m/s
- Final velocity (v_f) = -4 m/s (assuming the initial direction is positive)

he change in momentum is calculated as:

$$\Delta p = p_f - p_i = mv_f - mv_i = m(v_f - v_i)$$

$$\Delta p = 0.05 \text{ kg} \times (-4 \text{ m/s} - 4 \text{ m/s}) = 0.05 \times (-8) \text{ kg m/s} = -0.4 \text{ kg m/s}$$

The average force ($\mathbf{F}$) is calculated as:

$$\mathbf{F} = \frac{\Delta p}{\Delta t}$$

$$\mathbf{F} = \frac{0.4 \text{ kg m/s}}{0.01 \text{ s}} = 40 \text{ N}$$

3.

Let $m_A = 6$ kg, $v_A = 2$ m/s, $m_B = 4$ kg, and $v_B = -1.5$ m/s (negative since it moves in the opposite direction). Let v_{final} be the velocity of the combined mass.

The conservation of momentum equation is:

$$m_A v_A + m_B v_B = (m_A + m_B) v_{final}$$

Step 2: Solve for the final velocity

Substitute the given values into the equation:

$$(6 \text{ kg})(2 \text{ m/s}) + (4 \text{ kg})(-1.5 \text{ m/s}) = (6 \text{ kg} + 4 \text{ kg}) v_{final}$$

$$12 - 6 = 10 v_{final}$$

$$6 = 10 v_{final}$$

$$v_{final} = \frac{6}{10} \text{ m/s}$$

$$v_{final} = 0.6 \text{ m/s}$$

4.

- $m_1 = 6$ kg
- $v_{1i} = v$ (let the initial velocity of the 6 kg mass be v)
- $v_{2i} = 0$ (the second body is at rest)
- $v_f = \frac{1}{3} v$ (the final velocity is one third the initial velocity of the 6 kg mass)

Substituting these values, the equation becomes:

$$6(v) + m_2(0) = (6 + m_2)(\frac{1}{3} v)$$

Simplify the equation and solve for m_2:

$$6v = \frac{1}{3}(6 + m_2)v$$

Divide both sides by v:

$$6 = \frac{1}{3}(6 + m_2)$$

Multiply both sides by 3:

$$18 = 6 + m_2$$

Subtract 6 from both sides:

$$m_2 = 18 - 6$$

$$m_2 = 12$$

5.

- m_s be the mass of the shot
- v_s be the initial velocity of the shot ($140\ \text{ms}^{-1}$)
- m_b be the mass of the block ($13m_s$)
- v_b be the initial velocity of the block ($0\ \text{ms}^{-1}$)
- V be the final velocity of the combined shot and block

The conservation of momentum equation is:

$$m_s v_s + m_b v_b = (m_s + m_b)V$$

Step 2: Substitute the known values and solve for the final velocity

Substitute the given values into the equation:

$$m_s(140) + (13m_s)(0) = (m_s + 13m_s)V$$

$$140m_s = (14m_s)V$$

Divide both sides by $14m_s$:

$$V = \frac{140m_s}{14m_s} = 10\ \text{ms}^{-1}$$

6.

- Mass of body 1 (m_1) = 2 kg
- Initial speed of body 1 (u_1) = 6 m/s
- Mass of body 2 (m_2) = 4 kg
- Initial speed of body 2 (u_2) = 2 m/s
- Final speed of body 2 (v_2) = 4 m/s
- Final speed of body 1 (v_1) = ?

Substituting these values into the conservation of momentum equation:

$$(2\text{ kg})(6\text{ m/s}) + (4\text{ kg})(2\text{ m/s}) = (2\text{ kg})(v_1) + (4\text{ kg})(4\text{ m/s})$$

$$12 + 8 = 2v_1 + 16$$

$$20 = 2v_1 + 16$$

Now, solve the equation for v_1:

$$2v_1 = 20 - 16$$

$$2v_1 = 4$$

$$v_1 = \frac{4}{2}$$

$$v_1 = 2\text{ m/s}$$

7.

The formula is $a = \frac{F}{m}$

$$a = \frac{-150 \text{ N}}{50 \text{ kg}} = -3 \text{ m/s}^2$$

The acceleration of the body is -3 m/s^2.

Step 2: Calculate the time taken to come to rest

Using the kinematic equation $v = u + at$, where the final velocity (v) is 0 m/s, the initial velocity (u) is 30 m/s, and the acceleration (a) is -3 m/s^2, we can solve for the time (t).

The formula is $t = \frac{v - u}{a}$

$$t = \frac{0 \text{ m/s} - 30 \text{ m/s}}{-3 \text{ m/s}^2} = \frac{-30 \text{ m/s}}{-3 \text{ m/s}^2} = 10 \text{ s}$$

8.

- Mass of part 1: $m_1 = 2m$
- Mass of part 2: $m_2 = m$
- Mass of part 3: $m_3 = m$

Let the velocity of the second part be $\vec{v_2} = V\hat{i}$ and the velocity of the third part be $\vec{v_3} = V\hat{j}$. The velocity of the first part is $\vec{v_1}$.

Using the conservation of momentum equation from Step 1, we can write:

$$m_1\vec{v}_1 + m_2\vec{v}_2 + m_3\vec{v}_3 = 0$$

Substitute the values for the masses and known velocities:

$$(2m)\vec{v}_1 + (m)(V\hat{i}) + (m)(V\hat{j}) = 0$$

Solve for $\vec{v}_1$:

$$(2m)\vec{v}_1 = -mV\hat{i} - mV\hat{j}$$

$$\vec{v}_1 = \frac{-mV\hat{i} - mV\hat{j}}{2m} = -\frac{V}{2}(\hat{i} + \hat{j})$$

The speed of the first part, which is the third part mentioned in the problem (the heaviest one), is the magnitude of its velocity vector:

$$|\vec{v}_1| = \sqrt{(-\frac{V}{2})^2 + (-\frac{V}{2})^2} = \sqrt{\frac{V^2}{4} + \frac{V^2}{4}} = \sqrt{\frac{2V^2}{4}} = \sqrt{\frac{V^2}{2}} = \frac{V}{\sqrt{2}}$$

9.

- Mass of each bullet (m_b): 35×10^{-3} kg
- Velocity of each bullet (v_b): 400 ms^{-1}
- Number of bullets fired per second ($\frac{dn}{dt}$): 4 bullets/s

$$F = (\frac{dn}{dt}) \times m_b \times v_b$$

Step 3: Substitute the values and calculate the force

Substitute the given values into the formula:

$$F = (4) \times (35 \times 10^{-3}) \times (400)$$

$$F = 4 \times 35 \times 0.001 \times 400$$

$$F = 4 \times 35 \times 0.4$$

$$F = 140 \times 0.4$$

$$F = 56 \text{ N}$$

10.

The formula for kinetic energy is $KE = \frac{1}{2}mv^2$.

- Initial kinetic energy:
  $KE_i = \frac{1}{2}mv_i^2 = \frac{1}{2}(0.01 \text{ kg})(1000 \text{ m/s})^2 = 5000 \text{ J}$
- Final kinetic energy:
  $KE_f = \frac{1}{2}mv_f^2 = \frac{1}{2}(0.01 \text{ kg})(500 \text{ m/s})^2 = 1250 \text{ J}$
- Work done by gravity:
  $W_{gravity} = mgh = (0.01 \text{ kg})(10 \text{ m/s}^2)(50 \text{ m}) = 5 \text{ J}$

Step 3: Use the Work-Energy Theorem to find the work done against air resistance

According to the Work-Energy Theorem, the net work done on an object equals the change in its kinetic energy. The net work is the sum of the work done by gravity and the work done against air resistance.

$$W_{net} = W_{gravity} + W_{air} = KE_f - KE_i$$

We can rearrange this equation to solve for the work done against air resistance (W_{air}).

$W_{air} = KE_f - KE_i - W_{gravity}$

- Substitute the calculated values:
  $W_{air} = 1250 \text{ J} - 5000 \text{ J} - 5 \text{ J} = -3755 \text{ J}$

17,18.

$$P_{\text{initial}} = m_1 v_1 + m_2 v_2$$

Given values:

- Mass of the first body (m_1): 1 kg
- Initial velocity of the first body (v_1): 9 m/s
- Mass of the second body (m_2): 3 kg
- Initial velocity of the second body (v_2): 3 m/s

Since both bodies are traveling in the same direction, we can use positive values for their velocities.

$$P_{\text{initial}} = (1\ \text{kg})(9\ \text{m/s}) + (3\ \text{kg})(3\ \text{m/s})$$

$$P_{\text{initial}} = 9\ \text{kg} \cdot \text{m/s} + 9\ \text{kg} \cdot \text{m/s} = 18\ \text{kg} \cdot \text{m/s}$$

We already calculated the initial momentum (P_{initial}) to be 18 Ns. The final momentum (P_{final}) is the sum of the momenta of the two bodies after the collision.

$$P_{\text{final}} = m_1 v_{1f} + m_2 v_{2f}$$

$$18 \text{ Ns} = (1 \text{ kg}) v_{1f} + (3 \text{ kg})(2 \text{ m/s})$$

Given values:

- Mass of the first body (m_1): 1 kg
- Final velocity of the first body (v_{1f}): unknown
- Mass of the second body (m_2): 3 kg
- Final velocity of the second body (v_{2f}): 2 m/s

Step 3: Solve for the speed of the 1kg body after collision

Substitute the known values into the equation from Step 2 and solve for v_{1f}.

$$18 \text{ Ns} = (1 \text{ kg}) v_{1f} + 6 \text{ Ns}$$

$$18 - 6 = 1 \cdot v_{1f}$$

$$12 = v_{1f}$$

19.

- Mass of the bullet (m_b): $50 \text{ gm} = 0.05 \text{ kg}$
- Velocity of the bullet (v_b): 30 m/s
- Velocity of the gun (v_g): 1 m/s

We need to find the mass of the gun (m_g).

Step 2: Apply the conservation of momentum formula.

The formula for the conservation of momentum is:

$$m_b v_b + m_g v_g = 0$$

The velocity of the gun is in the opposite direction to the bullet's velocity, so we can treat it as a negative value.

$$(0.05 \text{ kg})(30 \text{ m/s}) + m_g(-1 \text{ m/s}) = 0$$

$$1.5 \text{ kg} \cdot \text{m/s} - m_g(1 \text{ m/s}) = 0$$

Step 3: Solve for the mass of the gun (m_g).

Rearrange the equation to solve for m_g:

$$m_g(1 \text{ m/s}) = 1.5 \text{ kg} \cdot \text{m/s}$$

$$m_g = \frac{1.5 \text{ kg} \cdot \text{m/s}}{1 \text{ m/s}}$$

$$m_g = 1.5 \text{ kg}$$

20.

The mass of each bullet is 10 g, which is equal to 0.01 kg. The velocity of each bullet is 400 m/s. The total momentum of the four bullets is the sum of the momentum of each individual bullet. Since each bullet has the same mass and velocity, the total momentum is:

$$P_{bullets} = (\text{number of bullets}) \times (\text{mass of a bullet}) \times (\text{velocity of a bullet})$$

$$P_{bullets} = 4 \times (0.01 \text{ kg}) \times (400 \text{ m/s})$$

$$P_{bullets} = 16 \text{ kg} \cdot \text{m/s}$$

The principle of conservation of momentum states that the total momentum of a system remains constant if no external forces act on it. Before firing, the total momentum of the machine gun and bullets is zero. After firing, the total momentum must also be zero. The momentum of the system after firing is the sum of the momentum of the bullets and the momentum of the machine gun.

$$P_{initial} = P_{final}$$

$$0 = P_{bullets} + P_{gun}$$

$$0 = 16 \text{ kg} \cdot \text{m/s} + (M \times V_{recoil})$$

Where M is the mass of the gun (10 kg) and V_{recoil} is the recoil velocity.

Step 3: Solve for the recoil velocity

Rearrange the equation from Step 2 to solve for the recoil velocity.

$$V_{recoil} = -\frac{P_{bullets}}{M}$$

$$V_{recoil} = -\frac{16 \text{ kg} \cdot \text{m/s}}{10 \text{ kg}}$$

$$V_{recoil} = -1.6 \text{ m/s}$$

LEARNERS TASK

CUQ'S

1. If two bodies of different masses are acted upon by the same force for the same time,

they will both acquire the same momentum. This is because the impulse (change in momentum) is equal to the product of force and time ($Impulse = F \times t$), and since the force and time are the same for both bodies, their change in momentum will be equal. Since both bodies start at rest (initial momentum is zero), their final momenta will be identical.

2. Action and reaction forces do not cancel each other because they act on different bodies. For forces to cancel, they must act on the same object, but action and reaction forces, by definition, are a pair where one is exerted on the second body and the other is exerted on the first body

Example:

When a person walks, they push backward on the ground (action). The ground pushes forward on them with an equal and opposite force (reaction), which is what allows them to move forward. The force of the person on the ground does not cancel the force of the ground on the person because they are acting on two different bodies (the person and the ground

4. A cannon recoils due to

Newton's Third Law of Motion. For every action, there is an equal and opposite reaction, so the force pushing the projectile forward (the action) creates an equal and opposite force that pushes the cannon backward (the reaction). This is also an example of the **conservation of linear momentum**, where the backward momentum of the cannon balances the forward momentum of the projectile to keep the total momentum of the system at zero (since both were initially at rest).

5. A man can get to the shore by using

Newton's third law of motion, which states that for every action, there is an equal and opposite reaction. By throwing an object away from the shore, the man exerts a force on the object (action), and the object exerts an equal and opposite force on him (reaction), propelling him toward the shore.

Why this works: Because the ice is perfectly smooth, there is no friction to hinder his movement. The only force he can use to move himself is the reaction force from throwing something

7.

The car will take a longer distance to stop than the lorry, but both will take the same amount of time to come to rest

. This is because the car has a smaller mass, so it has a greater deceleration when the same braking force is applied, causing it to travel a longer distance before stopping.

8. A rocket works on the principle of **conservation of linear momentum**. The expulsion of exhaust gases at high speed in one direction creates an equal and opposite force, or momentum, that propels the rocket forward.

- **Action and Reaction:** The rocket engine expels hot gases downwards (the action).
- **Equal and Opposite Momentum:** By the principle of conservation of linear momentum, the system must have a net momentum of zero before and after the expulsion. To maintain this, the gases ejected backward generate an equal amount of forward momentum for the rocket.
- **Thrust:** This forward momentum is the thrust that causes the rocket to accelerate and move forward

9. To reduce a body's momentum to half its original value, you can either

reduce its velocity by half while keeping the mass constant or **reduce its mass by half while keeping the velocity constant**. Other combinations are also possible, such as reducing the mass to one-fourth and doubling the velocity.

- **Halve the velocity:** Keep the mass the same and reduce the velocity by half ($m \times \frac{v}{2} = \frac{1}{2} mv$).
- **Halve the mass:** Keep the velocity the same and reduce the mass by half ($\frac{m}{2} \times v = \frac{1}{2} mv$).
- **Reduce mass and increase velocity:** Reduce the mass to one-fourth of its original value and double the velocity ($\frac{m}{4} \times 2v = \frac{1}{2} mv$).

JEE MAINS LEVEL

1.

Before breaking the body was at rest the linear momentum of the body was thus p=mv=0

The body breaks due to internal forces . As the external force acting on it is zero, its linear momentum will remain constant i.e., zero

The linear momentum of the first part is

$p_1 = m_1 v_1 = (200g)\left(12ms^{-1}\right)$ towards the east . For the total momentum to remain zero, the linear momentum of the other part must have the same magnitude and should be opposite in direction. It therefore moves towards the west. If its speed is v_2 its linear momentum is

$p_2 = m_2 v_2 = (100g)v_2$

Thus (200g) $\left(12ms^{-1}\right) = (100g)v_2$

or $v_2 = 24ms^{-1}$

The velocity of the other part is $24ms^{-1}$ towards the west.

2.

Given that mass of cannon = 198 kg

Fired shell of mass = 2 kg

$v = 50 ms^{-1}$

$M = m_1 + m_2$

$M = 198 + 2 = 200$

$U = 0$

From the law of conservation of momentum

$m_1 = 198$ $m_2 = 2Kg$ $V_1 = -V$ $V_2 = 50$

From the law of conservation of momentum

$MU = m_1 v_1 + m_2 v_2$

$200(0) = 198(-V) + 2(50)$

$0 = -198V + 100$

$198V = 100$

$V = \frac{100}{198} = \frac{1}{2}$ [approximately]

3.

1. **Initial Momentum:** Before the explosion, the total momentum is the mass of the shell (M) multiplied by its velocity (v).
   1. Initial Momentum = Mv
2. **Final Momentum:** After the explosion, the shell is in two parts:
   1. The first part has a mass (m) and its velocity is 0 (stationary).
   2. The second part has a mass of $(M - m)$ and an unknown velocity, let's call it v_2.
   3. Final Momentum = $m \times 0 + (M - m)v_2$
3. **Conservation of Momentum:** According to the law of conservation of momentum, the initial momentum must equal the final momentum.
   1. $Mv = m(0) + (M - m)v_2$
   2. $Mv = (M - m)v_2$
4. **Solve for the final velocity:** Rearrange the equation to find the velocity of the second part (v_2).
   1. $v_2 = \frac{Mv}{M - m}$

4.

The total momentum of the system before the collision is equal to the total momentum of the system after the collision. This can be expressed by the formula:

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

where m_1 and m_2 are the masses of the two trucks, u_1 and u_2 are their initial velocities, and v is their combined final velocity.

Step 2: Substitute the known values into the equation

Given values:

- Mass of the first truck (m_1): 1200 kg
- Initial speed of the first truck (u_1): 7 m/s
- Mass of the second truck (m_2): 1600 kg
- Initial speed of the second truck (u_2): 0 m/s

Substitute these values into the momentum equation:

$$(1200)(7) + (1600)(0) = (1200 + 1600)v$$

Step 3: Solve for the final velocity

Simplify the equation and solve for v:

$$8400 + 0 = (2800)v$$

$$8400 = 2800v$$

$$v = \frac{8400}{2800}$$

$$v = 3 \text{ m/s}$$

5.

1. **Calculate the net force (F_{net}):** The net force is the total upward force required to accelerate the rocket.
   1. $F_{net} = m \times a$
   2. $F_{net} = 500\,\text{kg} \times 20\,\text{m/s}^2 = 10000\,\text{N}$
2. **Calculate the total upward force (F_{thrust}):** The total upward force must overcome both the gravitational force and the net force.
   1. $F_{thrust} = F_{net} + F_{gravity}$
   2. $F_{gravity} = m \times g = 500\,\text{kg} \times 10\,\text{m/s}^2 = 5000\,\text{N}$
   3. $F_{thrust} = 10000\,\text{N} + 5000\,\text{N} = 15000\,\text{N}$
3. **Use the rocket equation to find the rate of mass expulsion:** The thrust is also related to the relative velocity of the ejected gas and the rate of mass expulsion (dm/dt).
   1. $F_{thrust} = v_{rel} \times (dm/dt)$
   2. $dm/dt = \dfrac{F_{thrust}}{v_{rel}}$
   3. $dm/dt = \dfrac{15000\,\text{N}}{250\,\text{m/s}} = 60\,\text{kg/s}$

6.

$$F_g = M \cdot g$$

Given values:

- $M = 2 \text{ kg}$
- $g = 10 \text{ m/s}^2$

$$F_g = 2 \text{ kg} \cdot 10 \text{ m/s}^2 = 20 \text{ N}$$

Step 3: Calculate the net force and acceleration

The net force (F_{net}) on the rocket is the difference between the upward thrust force and the downward gravitational force. According to Newton's second law, the net force is also equal to the mass of the rocket times its acceleration (a).

$$F_{net} = F_{thrust} - F_g = M \cdot a$$

To find the acceleration, rearrange the formula:

$$a = \frac{F_{thrust} - F_g}{M}$$

Substituting the calculated values:

$$a = \frac{5 \text{ N} - 20 \text{ N}}{2 \text{ kg}} = \frac{-15 \text{ N}}{2 \text{ kg}} = -7.5 \text{ m/s}^2$$

7.

The weight of the rocket (W) is the force of gravity acting on it. Using the formula $W = m \cdot g$, where g is the acceleration due to gravity (approximately 9.8 m/s^2):

$$W = (8000 \text{ kg}) \cdot (9.8 \ m/s^2)$$

$$W = 78400 \text{ N}$$

Step 3: Use the thrust equation to find the mass ejection rate

The thrust force (F_{thrust}) produced by the rocket's exhaust is given by the equation $F_{thrust} = v_e \cdot \frac{dm}{dt}$, where $\frac{dm}{dt}$ is the mass of gas ejected per second. To overcome t rocket's weight, the thrust must equal the weight.

$$F_{thrust} = W$$

$$v_e \cdot \frac{dm}{dt} = 78400 \text{ N}$$

Now, solve for $\frac{dm}{dt}$:

$$\frac{dm}{dt} = \frac{78400 \text{ N}}{v_e}$$

$$\frac{dm}{dt} = \frac{78400 \text{ N}}{800 \ m/s}$$

$$\frac{dm}{dt} = 98 \text{ kg/s}$$

8.

- Mass of one bullet (m_b): 100 gm = 0.1 kg
- Number of bullets per second (n): 10 bullets/s
- Velocity of a bullet (v_b): 600 m/s

The total mass of the bullets fired per second (M_b) is:

$$M_b = m_b \times n = 0.1 \text{ kg} \times 10 = 1 \text{ kg}$$

The total momentum of the bullets per second ($P_{bullets}$) is:

$$P_{bullets} = M_b \times v_b = 1 \text{ kg} \times 600 \text{ m/s} = 600 \text{ kg} \cdot \text{m/s}$$

According to Newton's Second Law, the force is equal to the rate of change of momentum. The force exerted on the bullets is the momentum of the bullets per second. By Newton's Third Law, the recoil force on the machine gun is equal in magnitude to the force on the bullets9.

Therefore, the recoil force (F_{recoil}) is:

$$F_{recoil} = 600 \text{ N}$$

Step 3: Calculate the acceleration of the machine gun

Using Newton's Second Law ($F = ma$), the acceleration of the machine gun can be found by dividing the recoil force by the mass of the machine gun.

- Mass of the machine gun (m_{gun}): 100 kg
- Recoil force (F_{recoil}): 600 N

The acceleration of the machine gun (a_{gun}) is:

$$a_{gun} = \frac{F_{recoil}}{m_{gun}} = \frac{600 \text{ N}}{100 \text{ kg}} = 6 \text{ m/s}^2$$

9.

Given:

- Mass of a bullet, $m = 50 \text{ gm} = 0.050 \text{ kg}$
- Speed of a bullet, $v = 1000 \text{ m/s}$

The impulse of one bullet is:

$$\Delta p = mv$$

$$\Delta p = (0.050 \text{ kg})(1000 \text{ m/s})$$

$$\Delta p = 50 \text{ kg} \cdot \text{m/s}$$

The average force exerted by the gunner is equal to the total change in momentum per unit of time.

$$F = \frac{\text{Total momentum}}{\text{Time}}$$

The total momentum is the momentum of a single bullet multiplied by the number of bullets fired (N_s) in one second.

Given:

- Maximum force, $F = 180 \text{ N}$

$$F = N_s \cdot (\Delta p)$$

$$180 \text{ N} = N_s \cdot (50 \text{ kg} \cdot \text{m/s})$$

$$N_s = \frac{180 \text{ N}}{50 \text{ kg} \cdot \text{m/s}}$$

$$N_s = 3.6 \text{ bullets/s}$$

To find the maximum number of bullets that can be fired per minute, multiply the bullets per second by 60.

$$N_{min} = N_s \cdot 60 \text{ s/min}$$

$$N_{min} = 3.6 \text{ bullets/s} \cdot 60 \text{ s/min}$$

$$N_{min} = 216 \text{ bullets/min}$$

10.

The problem provides the following information:

- Mass of air, $m = 2 \text{ gm} = 0.002 \text{ kg}$
- Speed of the air, $v = 2 \text{ m/s}$
- Time taken, $\Delta t = 5 \text{ s}$

The change in momentum (Δp) is the momentum of the air that exits the balloon. Since the air is initially at rest inside the balloon and then leaves with a speed v, the change in momentum is the product of the mass of the air and its velocity.

$$\Delta p = m \cdot v$$

$$\Delta p = (0.002 \text{ kg}) \cdot (2 \text{ m/s})$$

$$\Delta p = 0.004 \text{ kg} \cdot \text{m/s}$$

Step 3: Calculate the average thrust

Now, substitute the value of the change in momentum and the time into the thrust formula:

$$F_{avg} = \frac{\Delta p}{\Delta t}$$

$$F_{avg} = \frac{0.004 \text{ kg} \cdot \text{m/s}}{5 \text{ s}}$$

$$F_{avg} = 0.0008 \text{ N}$$

20.(i),(ii)

The law of conservation of momentum states that the total momentum before firing is equal to the total momentum after firing, provided no external forces act on the system.

- Mass of bullet, $m_b = 50\,\text{gm} = 0.05\,\text{kg}$
- Velocity of bullet, $v_b = 30\,\text{m/s}$
- Recoil velocity of gun, $v_g = 1\,\text{m/s}$
- Mass of gun, $M_g = ?$

Initial momentum (before firing) is 0 (both gun and bullet are at rest).
Final momentum (after firing) is $m_b v_b + M_g v_g$. We assign the bullet's direction as positive and the gun's recoil direction as negative.

$$0 = (0.05\,\text{kg})(30\,\text{m/s}) + M_g(-1\,\text{m/s})$$

$$0 = 1.5\,\text{kg} \cdot \text{m/s} - M_g(1\,\text{m/s})$$

$$M_g = \frac{1.5\,\text{kg} \cdot \text{m/s}}{1\,\text{m/s}}$$

$$M_g = 1.5\,\text{kg}$$

The momentum imparted per second by the bullets is $n \times m_b \times v_b$.
This must be balanced by the momentum change of the gun system (or the force applied to hold it steady). The final steady velocity of recoil is given by the formula $V_g = \frac{n \times m_b \times v_b}{M_g}$ (which is essentially balancing the total forward momentum with total backward momentum over time).

$$V_g = \frac{(1 \text{ bullet/s}) \times (0.01 \text{ kg}) \times (400 \text{ m/s})}{10 \text{ kg}}$$

$$V_g = \frac{4 \text{ kg} \cdot \text{m/s}}{10 \text{ kg}}$$

$$V_g = 0.4 \text{ m/s}$$

The velocity of recoil of the gun is **0.4 m/s** (in the opposite direction of the bullets).