CHAPTER = 3 MOTION

BOOK NUMERICAL

1 **A car weighing 9800 N is moving with a speed of 40 Km/h. On the Application of breaks, it comes to rest after traveling a distance of 50 meters. Calculate die average retarding force?**

Data:

$W = 9800\ N$

$$m = \frac{W}{g}$$

$$m = \frac{9800}{9.8}$$

$m = 1000\ kg$

$$v_i = 40km/h = \frac{40 \times 1000}{60 \times 60}.$$

$v_i = 11.11 m/sec$

$v_f = 0$

$F = ?$

$S = 50$ meters

SOLUTION:

$$2as = v_f^2 - v_i^2$$

$$a = \frac{v_f^2 - v_i^2}{2s}$$

$$a = \frac{(0)^2 - (11.11)^2}{2(50)}$$

$$a = \frac{-123 \cdot 4321}{100}$$

$a = -1.234321\ m/sec^2$

$F = ma$

$F = 1000 \times (-1234.321)$

$F = -1234.321\ N$

$\boxed{F = -1234.321\ N}$

2 **A helicopter weighs 3920 Newton. Calculate the upwards force on it if it is ascending at a rate of $2m/sec^2$. What will be force on helicopter if it is moving up with the constant speed of 4 m/sec.**

Data:

$W = 3920\ N$

$$m = \frac{W}{g}$$

$$m = \frac{3920}{9.8}$$

$m = 400\ kg$

(i) $a = 2m/s^2$ up (ii) $v = 4m/s$ up

(i) $F_e = ?$ (ii) $F_e = ?$

SOLUTION:

(i) Net force $= F - W$

$F_e = F - W$

$F = F_e + W$

$F = ma + W$

$F = (400 \times 2) + 3920$

$F = 800 + 3920 = 4720\ N$

(ii) Since the helicopter is moving with constant speed, therefore its acceleration is equal to zero

$F_e = F - W$

$F = F_e + W$

$F = 0 + 3920 = 3920\ N$

3 **A 100 gm bullet is fired from a 10 kg gun with a speed of 1000 m/sec what is the speed of recoil of the gun.**

Data:	**SOLUTION:**
$m_1 = 100\text{ g} = \frac{100}{1000} = 0.1\,kg$ $m_2 = 10\text{ kg}$ Initially the bullet is at rest $U_1 = 0$ Initially the gun is at rest $U_2 = 0$ $V_1 = 1000\text{ m/s}$ $V_2 = ?$	Applying the Law of conservation of momentum $m_1U_1 + m_2U_2 = m_1V_1 + m_2V_2$ $0.1(0) + 10(0) = 0.1(1000) + 10V_2$ $0 = 100 + 10V_2$ $-100 = 10V_2$ $-\frac{100}{10} = V_2$ $V_2 = -10ms^{-1}$

4 **A machine gun fires 10 bullets per second at a target. Each bullet weighs 20 gm and has a speed of 1500 m/sec. Find the force necessary to hold the gun in position.**

Data:	**SOLUTION:**
number of bullets $n = 10$ t = 1 second mass of each bullet $m_1 = 20\text{ g}$ $m_1 = \frac{20}{1000} = 0.02\,kg$ (mass of 10 bullets) $m = 10 \times 0.02$ $m = 0.2\text{ kg}$ Initially velocity of the bullets $V_i = 0$ final velocity of the bullets $V_f = 1500\text{ m/s}$ $F = ?$	Acceleration of the bullets $a = \frac{V_f - V_i}{t}$ $a = \frac{1500 - 0}{1}$ $a = 1500\text{ m/s}^2$ $F = m\,a = 0.2 \times 1500$ $F = 300\text{ N}$

5 A 50 gm bullet is fired into a 10 kg block that is suspended by a long cord so that it can swing as a pendulum. If the block is displaced so that its centre of gravity rises by 10cm. What was the speed of the bullet?

Data:

$m_1 = 50\text{ g} = \frac{50}{1000} = 0.05\ kg$

$m_2 = 10\text{ kg}$

Initial velocity of the bullet $U_1 = ?$

initial velocity of the gun $U_2 = 0$

final velocity of the bullet $V_1 = V$

final velocity of the gun $V_2 = V$

centre of gravity rise $h = 10\text{ cm} = 0.1\text{ m}$

SOLUTION:

Applying the Law of conservation of momentum

$m_1U_1 + m_2U_2 = m_1V_1 + m_2V_2$

$0.05\,U_1 + 10(0) = 0.05\,V + 10V$

$0.05\,U_1 = 10.05\,V \quad \ldots\ldots\ldots..(i)$

After the collision block-bullet system moves like a pendulum so their K.E is converted into P.E as they rise,

$\therefore$ loss of K.E = P.E gained

$\frac{1}{2}(m_1 + m_2)V^2 = (m_1 + m_2)gh$

$\frac{1}{2}V^2 = g\,h$

$V = \sqrt{2g\,h} = \sqrt{2 \times 9.8 \times 0.1}$

$V = \sqrt{1.96} = 1.4\ m/s$

Putting the value of v = 1.4 m/s in eq (i)

$0.05\,U_1 = 10.05 \times 1.4$

$U_1 = \frac{10.05 \times 1.4}{0.05} = 281.4\ m/s$

6 A 70-gram ball collides with another ball of mass 140 gram. The initial velocity of the first ball is 9m/s to right while the second ball is at rest. If the collision were perfectly elastic, what would be the velocity of two balls after the collision?

Data:

$m_1 = 70\text{ g} = \frac{70}{1000} = 0.07\ kg$

$m_2 = 140\text{ g} = \frac{140}{1000} = 0.14\ kg$

Initially veocity of first ball $U_1 = 9m/s$

Initially veocity of second ball $U_2 = 0$

$V_1 = ?$ $V_2 = ?$

SOLUTION:

Velocity V_1 of golf ball after collision is given by:

$$V_1 = \frac{(0.07 - 0.14)}{(0.07 + 0.14)} \times 9 + \frac{(0.07 - 0.14)}{(0.07 + 0.14)} \times 0$$

$$V_1 = \frac{(-0.07)}{(0.21)} \times 9 + 0 = -3\ m/s$$

$$v_2 = \frac{(m_2 - m_1)}{(m_1 + m_2)}u_2 + \frac{2m_1}{(m_1 + m_2)}u_1$$

$v_1 = \frac{(m_1 - m_2)}{(m_1 + m_2)} u_1 + \frac{2m_2}{(m_1 + m_2)} u_2$ $V_1 = \frac{(0.07 - 0.14)}{(0.07 + 0.14)} \times 9 + \frac{2 \times 0.14}{(0.07 + 0.14)} \times 0$	$V_2 = \frac{(0.14 - 0.09)}{(0.07 + 0.14)} \times 0 + \frac{2 \times 0.07}{(0.07 + 0.14)} \times 9$ $V_2 = 0 + \frac{0.14 \times 9}{(0.21)}$ $V_2 = 6\ m/s$

7 A truck weighing 2500 kg and moving with a velocity of 21m/s collides with a stationary car weighing 1000 kg. The truck and car move together after the impact. Calculate their common velocity?

Data: **Data:** $m_1 = 2500\ kg$ $m_2 = 1000\ kg$ Initially veocity of truck $U_1 = 21\ m/s$ Initially veocity of car $U_2 = 0$ The truck and car move together after the impact $V_1 = V$ $V_2 = V$ $V = ?$	**SOLUTION:** Applying the Law of conservation of momentum $m_1U_1 + m_2U_2 = m_1V_1 + m_2V_2$ $2500(21) + 1000(0) = 2500(V) + 1000V_2$ $52500 + 0 = 2500\ V + 1000\ V$ $52500 = 3500\ V$ $\frac{52500}{3500} = V$ $V = 15\ m/s$

ADDITIONAL NUMERICAL

1 A car weighing 21560N is moving upon an inclined plane which rises 1.0m in each 10.0 m with an acceleration of 1.0m/s^2. If the frictional force is negligible, how much force is exerted by the engine?

<u>Data:</u>

W = 21560 N

h = 1 m

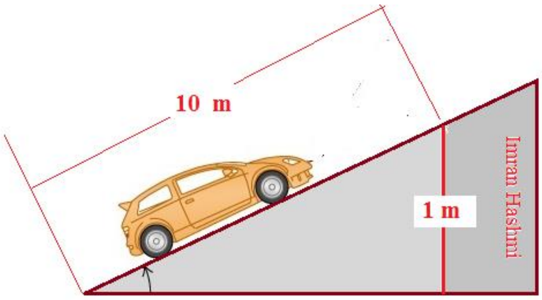
s = 10 m

g = 9.8 m/s^2

<u>TO DETERMINE</u>

Tension T =?

Time taken t = ?



<u>SOLUTIONS</u>

The resultant force acting on the car is given by

$$F - mg\sin\theta = ma \quad \ldots\ldots(i)$$

From figure

$$\sin\theta = \frac{1}{10} \ldots\ldots\ldots\ldots\ldots(ii)$$

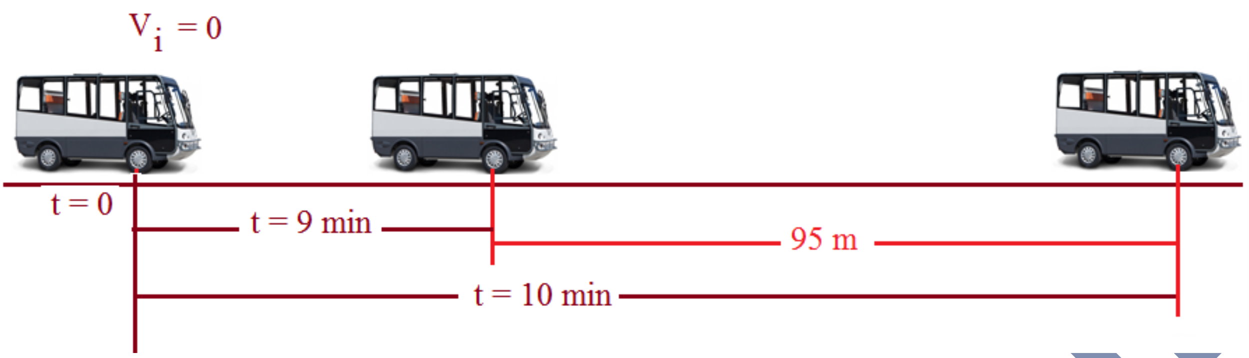
putting the given valve in equation (i)

$$F - \left(\frac{21560}{9.8}\right) \times 9.8\left(\frac{1}{10}\right) = \left(\frac{21560}{9.8}\right)(1.0)$$

$$F - 2156 = 2200$$

$$F = 4356N$$

2 A minibus starts moving from a position of the rest at a bus stop with uniform acceleration. During the 10th minute of its motion, it covers a distance of 95 meters. Calculate its acceleration and the total distance it covers in 10 minutes.



<u>Data:</u>

$V_i = 0$

S = 95 m(during the 10th second)

<u>TO DETERMINE</u>

Acceleration a =?

Total distance = ?

<u>SOLUTIONS</u>

The car covered a distance in the first 9 min

$$S_9 = V_i t + \frac{1}{2} g t^2$$

$$S_9 = 0 \times t + \frac{1}{2} \times a (9 \times 60)^2$$

$$S_9 = 0 + (0.5 \times a \times 291600)$$

$$S_9 = 145800a \ldots\ldots\ldots (i)$$

The car covered a distance in the first 9 second

$$S_{10} = V_i t + \frac{1}{2} g t^2$$

$$S_{10} = 0 \times t + \frac{1}{2} \times a (10 \times 60)^2$$

$$S_{10} = 0 + (0.5 \times a \times 360000)$$

$$S_{10} = 180000a \ldots\ldots (ii)$$

According to the given condition

$$S_{10} - S_9 = 95$$

Substituting the expression for S_9 and S_{10} from equation (i) and (ii) in the above equation

$$180000a - 145800a = 95$$

$$34200a = 95$$

$$a = 2.78 \times 10^{-3} ms^{-2}$$

Total distance covered by a minibus in 10 minutes, using equation (ii)

$$S_{10} = 180000a \ldots\ldots\ldots\ldots (ii)$$

Put $a = 2.78 \times 10^{-3} ms^{-2}$ in above equation

$$S_{10} = 180000 \times 2.78 \times 10^{-3}$$

$$S_{10} = 500m$$

3 **A 100gm bullet is fired into a 12 kg block which is suspended by a long cord, such that it can swing like a pendulum. If the bullet is embedded in the block and the block rises by 5cm, what was the speed of the bullet?**

[119.78 m/s]

Data:

Mass of the bullet

m = 100 gm = 0.1 kg

mass of the block M = 12 kg

Height to which the block rises

h = 5 cm = 0.05 m

Initial speed of the bullet u_1 = ?

Solution:

Applying law of conservation of momentum we get:

Total initial momentum = total final momentum.

$m U_1 + M U_2 = m V_1 M V_2$

Initial momentum of the block is zero because it was initially at rest ($u_2 = 0$).

After collision the bullet is embedded into the block and both move with the same velocity, let it be $V_1 = V_2 = V$, Then

$m U_1 = (m + M) V$

$\therefore 0.1 \times U_1 = (0.1 + 12)V$

$0.1 U_1 = 12.1 V$ ………. (i)

After the collision block-bullet system moves like a pendulum so their K.E is converted into P.E as they rise,

$\therefore$ loss of K.E = P.E gained

$$\frac{1}{2}(m+M)V^2 = (m+M)gh$$

$$\frac{1}{2}V^2 = 9.8 \times 0.05$$

$$V^2 = 0.98$$

$$V = \sqrt{0.98}$$

$$V = 0.99 \text{ m/s}$$

Substituting this value of V in equation (i) we get:

$$0.1 U_1 = 12.1 V$$

$$0.1 U_1 = 12.1 \times 0.98$$

$$0.1 U_1 = 11.978$$

$$U_1 = 11.978 / 0.1$$

$$U_1 = 119.78 / 0.1$$

$\therefore$

The speed of the bullet before collision with the block was 119.78 m/s.

4 A 150 g bullet is fired from 15 Kg gun with a speed of 1500 m/s. What is the speed of recoil of the gun?

Data:

Mass of the bullet m = 150 g
= 0.150 kg
Mass of the gun M = 15 kg
Speed of the bullet v_1 = 1500 m/s
Speed of recoil of the gun v_2 = ?

Solution:

According to law of conservation of momentum:
Total initial momentum = Total final momentum
Initially the gun and the bullet both are at rest, therefore, initial momentum of both is zero.

$$0 = m v_1 + M v_2$$

$$0 = 0.150 \times 1500 + 15 \times v_2$$

$$-\frac{0.150\times1500}{15}=v_2$$

$$\boxed{v_2 = -15 \text{ m/s}}$$

5 A 100 gm golf ball at rest moving with a velocity of 20 m/s collide with a 8Kg steel ball at rest. If the collision is elastic, computer the velocities of both balls after the collision.

Data:

Mass of golf ball m_1 = 100g = 0.1 kg
Initial velocity of golf ball u_1 = 20 m/s
Mass of steel ball m_2 = 8 kg
Initial velocity of steel ball u_2 = 0
Final velocities of both balls v_1 & v_2 = ?

Solution:

Velocity v_1 of golf ball after collision is given by:

$$v_1=\frac{(m_1-m_2)}{(m_1+m_2)}u_1+\frac{2m_2}{(m_1+m_2)}u_2$$

$$v_1=\frac{(0.1-8)}{(0.1+8)}\times20+\frac{2\times8}{(0.1+8)}\times0$$

$$v_1=-\frac{7.9}{8.1}\times20+0$$

$$v_1=-\frac{7.9}{8.1}\times20+0$$

$$\boxed{v_1 = -19.506 \text{ m/s}}$$

Velocity v_2 of steel ball after collision is given by:

$$v_2=\frac{2m_1}{(m_1+m_2)}u_1+\frac{(m_2-m_1)}{(m_1+m_2)}u_2$$

$$v_2=\frac{2\times0.1}{(0.1+8)}\times20+\frac{(8-0.1)}{(0.1+8)}\times0$$

$$v_2=-\frac{2\times0.1}{8.1}\times20+0$$

$$\boxed{v_2 = 0.494 \text{ m/s}}$$

6 A wooden block having 10kg mass is suspended b a long cord that can swing as a pendulum. A 50 gm bullet is fired which lodges itself into the block. Due to the impact, the center of gravity of the block is raised by 10cm. What was the initial speed of the bullet?

[281.4 m/s]

Data:

$$Mass\ of bullet = m = 50gm$$

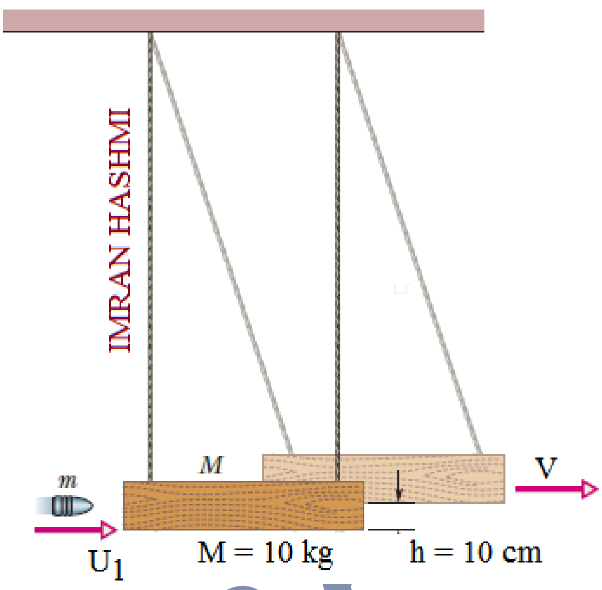
$$m = \frac{50}{1000} = 0.05kg$$

Mass of block = M = 10 kg

$$Height of block = h = 10cm$$

$$h = \frac{10}{100} = 0.1m$$

Speed of bullet = u_1 = ?



SOLUTION:

According to law of conservation of momentum.

$$M_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$mu_1 + M \times 0 = mv + Mv$$

$$u_1 = \frac{(m+M)}{m}v - - - - -(i)$$

$$\because Initial velocity of block = u_2 = 0$$

$$Final velocity bullet + block = v$$

K.E of bullet + block = P.E of bullet + block

$$\frac{1}{2}(\cancel{m+M})v^2 = (\cancel{m+M})gh$$

$$v = \sqrt{2gh}$$

$$v = \sqrt{2 \times 9.8 \times 0.1}$$

$$v = 1.4\ m/s$$

putting this in Eq. (i),we get

$$u_1 = \left(\frac{0.05+10}{0.05}\right)(1.4)$$

$\boxed{u_1 = 281.4\ m/sec.}$ Ans