X-Newton's Laws of Motion

Exercise Solutions

Objective Questions

LEVEL 1

1. (b)

2. (c)
$1\text{ gf} = 1\text{ gwt} = 10^{-3} \times 9.8\text{ N} = 980\text{ dyne}$

3. (a)
Recoil velocity, $V = -mv/M = -10^{-2} \times 250/5 = -0.5$ m/s

4. (b)
$F = ma = m(v-u)/t$
Here, $u = 0 \Rightarrow v = Ft/m = 3\times10^5\times10/(5\times10^4) = 60$ m/s

5. (a)
Recoil velocity, $V = -mv/M \Rightarrow M = -mv/V$
$M = 60\times0.07/4 = 1.05$ Kg

6. (c)
Recoil velocity, $V = -mv/M \Rightarrow M = -mv/V$
$M = 60\times0.07/4 = 1.05$ Kg

7. (c)
Ratio of inertia = Ratio of mass = 2:1

8. (a)

9. (a)
F = Change in momentum/time
Here, change in momentum $= 0.25\times40 = 10$ kg.m/s
$F = 10/0.1 = 100$ N

10. (c)
Initial acceleration of the block = Force on block/Mass of block
Force on block is due to jet water
Force applied by jet water = Change in momentum of jet water per second
Per second, mass of water released = 2 kg
Momentum change per second $= 2\times15 = 30$ kg.m/s
Thus, force applied by jet water = 30 N
Acceleration of block $= 30/2 = 15\text{ m/s}^2$

11. (a)
We know that, change in momentum (or Impulse) = Force$\times$Time
Time = Change in momentum/Force $= 20\times50/1000 = 1$ s

12. (a)

13. (b)
Change in momentum = m(v-u)
Here, $v = 72\times1000/3600$ m/s = 20 m/s and u = 10 m/s
Change in momentum = $2000\times(20-10)$ = 20,000 kg.m/s

LEVEL 2

1. (d)
Momentum transferred = mv, where v is the velocity of dumbbell just before touching the floor
Using third equation of motion, $v^2 = u^2 + 2as$
$\Rightarrow v = \sqrt{(2gh)} = \sqrt{(2\times10\times0.9)} = 3\sqrt{2}$ m/s
Momentum transferred = $mv = 20\times3\sqrt{2} = 60\sqrt{2}$ kg.m/s

2. (d)
Using third equation, $s = (v^2 - u^2)/2a$
Here v = 0 and 'a' is same for both cases.
Thus s (stopping distance) is proportional to square of initial speed.
Hence s will be 9 times i.e. 180 m

3. (b)
Using third equation, $s = (v^2 - u^2)/2a$
Here v = 0, u = 15 m/s and 'a' is acceleration
$a = -u^2/2s = -225/(2\times25) = -4.5$ m/s^2
Force = ma = $1500\times(-4.5) = -6750$ N

4. (c)
Velocity after falling a height h = $\sqrt{(2gh)}$ i.e. same for both masses
All other given properties depend on mass

5. (b)
$m = F/a \Rightarrow m_1 = 5/10 = 0.5$kg and $m_2 = 5/20 = 0.25$ kg
If both masses are tied together, $a = F/(m_1+m_2) = 5/0.75 = 6.67$ m/s^2

6. (a)
Maximum allowed force = 75g = 750N
Force on rope when body is accelerating = mg + ma
$\Rightarrow F_{max} = mg + ma_{max}$
$\Rightarrow a_{max} = (F_{max} - mg)/m = (750-600)/60 = 2.5$ m/s^2

7. (d)

8. (d)
Change in momentum = m(v-u)
Here, m = 0.5 kg, v = 15 m/s and u = -10 m/s $\Rightarrow$ Change in momentum = 0.5(15-(-10))
Change in momentum = 12.5 kg.m/s
F = Change in momentum/time $\Rightarrow$ F = 12.5/(1/50) = 625 N

9. (b)
Using third equation, $s = (v^2 - u^2)/2a$
Here v = 0 and 'a' is same for both cases.
Thus s (stopping distance) is proportional to square of initial speed.
Hence s will be 4 times i.e. 16 m

10. (a)

Change in momentum = Area under the curve

Area = -4 + 4 –1 +1 = 0

Subjective Questions

1. This happens due to inertia of motion. When the bus or train is stopped suddenly, a passenger sitting inside tends to fall forward. Because the lower part of the body comes to rest with the bus while the upper part tends to continue its motion due to inertia.

2. When a carpet is beaten with a stick, the dust comes out of it because of law of inertia. Initially the dust particles are at rest along with the carpet. Beating the carpet with the stick makes the carpet move but the dust particles remain at rest due to inertia at rest, thus the dust gets detached from the carpet.

3. (i) Initial momentum = $20\times5 = 100$ kg.m/s

Final momentum = 0

(ii) Change in momentum = m(v-u) = -100 kg.m/s

4. We know that Mass = Density×Volume $\Rightarrow m = p\times4\pi r^3/3$

For second sphere, $m' = p\times4\pi(3r)^3/3 = 27(p\times4\pi r^3/3) = 27m$

Momentum = $mv = m'v' \Rightarrow v' = mv/m' = v/27$

5. Acceleration, $a = (v-u)/t = (25-10)/4 = 15/4$ m/s^2

Force = ma = $0.1\times15/4 = 0.375$ N

6. Here v is constant $\Rightarrow$ acceleration is zero

Since F = ma $\Rightarrow$ Force is zero

7. (b)

Force acting on gun and the bullet is same (action-reaction pair)

Acceleration of gun is less because it has more mass than the bullet (a = F/m)

8. (F)

Force is constant $\Rightarrow$ Acceleration is constant

We know that, $s = ut + ½ at^2$

We can see that displacement (s) is not directly proportional to time (t).

9. We know that $v^2 = u^2 + 2as \Rightarrow a = (v^2 - u^2)/2s$

Here $v = 0 \Rightarrow a = -u^2/2s$

$\Rightarrow$ Acceleration is 4 times when initial speed is doubled (stopping distance (s) is same for both bodies)

Since, F = ma $\Rightarrow$ Force will 4 times for the second mass $\Rightarrow$ F' = 4F

10. Since $v^2 = u^2 + 2as \Rightarrow a = (v^2 - u^2)/2s$

Here $v = 0 \Rightarrow a = -u^2/2s$

Here, $u = 36\times1000/3600 = 10$ m/s $\Rightarrow a = -100/50 = -2$ m/s^2

F = ma $\Rightarrow$ F = 2500× (-2) = -5000 N (Negative sign indicates that force is resistive)

11. Since $v^2 = u^2 + 2as \Rightarrow a = (v^2 - u^2)/2s$

Here $v = 0 \Rightarrow a = -u^2/2s$

Here, s = 51 – 1 = 50m and $u = 36\times1000/3600 = 10$m/s

$\Rightarrow a = -100/(2\times50) = -1$ m/s^2

F = ma => F = 2000× (-1) = -2000 N (Negative sign indicates that force is retarding in nature)

12. Change in momentum = m(v–u)
Here, v = 20 m/s, u = -20 m/s and m = 4 kg
$\Rightarrow$ Change in momentum = 4(20-(-20)) = 160 kg.m/s
(i) Force = Change in momentum/Time = 160/0.5 = 320 N
(ii) Impulse = Change in momentum = 160 kg.m/s

13. If a man falls on a soft-landing site like heap of sand, it compresses and the man takes a longer time to come to stop. The rate of change of momentum is less due to which a smaller stopping force acts on the man and he does not get hurt.
If the man lands on hard ground like cement floor, then his momentum will be reduced to zero in a very short time. The rate of change of momentum will be large due to which a large opposing force will act on the man. This force can lead to injuries to the man.

14. According to Newton's third law, wall also exerts the same force on our hand (reaction pair). Due to this force our hand feel pain.

15. A horse pushes the ground in the backward direction. According to Newton's third law of motion, a reaction force (friction) is exerted by the Earth on the horse in the forward direction. As a result, the cart moves forward.

16. Because when a swimmer applies a force backward, water exerts an opposite force on the swimmer (i.e. in the forward direction) so he is able to move forward.

17. Force applied by the stretched spring is same for both masses.
Since F = ma $\Rightarrow$ F = 2×6 = 12 N
For second block, a = F/m = 12/4 = 3 m/s^2

18. There is no net external force on the rifle-bullet system so it's momentum must be conserved. Initial momentum of the rifle-bullet system is zero since both are at rest. When bullet is fired, it moves in the forward direction with a certain momentum. To keep the net momentum of system zero, the rifle moves backward with momentum same as that of the bullet.
Let m and M be the mass of bullet and rifle respectively. Let v and V be the velocity of bullet and rifle respectively just after firing.
Conserving the momentum $\Rightarrow$ mv + MV = 0 $\Rightarrow$ V = -mv/M

19. Rockets work due to Newton's third law of motion. The rocket pushes out gases in the backward direction (action force). The gases push the rocket in forward direction (reaction force).

20. When a balloon is pierced with a pin, the air rushing out of the balloon through the hole pushes the air in the surrounding. Due to Newton's third laws of motion, the air surrounding the balloon also pushes it with equal force in opposite direction and hence the balloon moves.

21. Due to Newton's third law of motion, astronaut will experience a recoil in backward direction.
We know that recoil velocity, V = -mv/M
V = -0.05×400/120 = -0.16 m/s (Negative sign indicates that recoil velocity is opposite to that of bullet).

22. Momentum of the system will be conserved just before and after landing on the skateboard as there is no external force on the system in horizontal direction.
Initial momentum = mv = 58×3 = 174 kg.m/s
Final momentum of the system = m'v' = (58+2)v'
Conserving the momentum, (58+2)v' = 174 $\Rightarrow$ v' = 174/60 = 2.9 m/s