SOLUTIONS

4.1: Momentum and Newton's laws of motion

1. **A**
The net force F_{net} acting on the car is the difference between the two opposing forces:
F_{net} = 1600 N - 1200 N = 400 N
Using Newton's second law F = ma, the acceleration *a* is given by:
$a = \frac{F_{net}}{m} = \frac{400\,N}{850\,kg} = 0.47\,m/s^2$. Therefore, the correct answer is A.

2. **B**
For an object moving with uniform acceleration, the resultant force must be constant because the acceleration is uniform. According to Newton's second law, F = ma, where m is constant and a is uniform, hence F is constant. Therefore, the correct answer is B.

3. **C**
Force is defined as the rate of change of momentum. According to Newton's second law of motion, F = $\frac{dp}{dt}$, where p is momentum (p = mv). Therefore, the correct definition of force is C: the rate of change of momentum.

4. **A**
F = ma
w – f = ma
$0.5 \times 9.8 - f = 0.2 \times 2$
f = 3.5 N

5. **C**
Force = rate of change of momentum = $\Delta p / \Delta t$

6. **B**
Mass resists changes in motion according to Newton's first law of motion; hence it does not depend on location but is a measure of an object's resistance to changes in its state of motion.

7. **D**
To find the average force exerted by the cushion on the snooker ball, use the change in momentum over time. The change in momentum is from 14.0 m / s to 7.0 m / s, opposite in direction, over 0.6 s. Calculating (14.0 + 7.0)m / s × 0.2 kg / 0.6 s results in approximately 7.0 N.

8. **C**
Mass of an object is a measure of the amount of matter it contains. It represents the resistance of an object to changes in its motion, which is termed as inertia. Inertia is a key concept in Newton's first law of motion.
Therefore, the most appropriate description for the mass of an object is "the resistance of the object to changes in motion".

9. **D**
As the box slides down, it speeds up due to gravity. The frictional force, which opposes motion, remains constant.
As the box gains speed, the net accelerating force decreases because the constant friction takes up a larger portion of the gravitational force. Hence, acceleration decreases, but resistive force stays constant. Option D reflects this situation.

10. **C**
For the drone to hover, the downward momentum of the air must equal the upward momentum.
Total air mass pushed down by one propeller in 1 second = 0.400 kg
Total air mass pushed down by all propellers in 1 second = 4×0.400 kg = 1.60 kg
Weight of drone = $m \times g = 1.20 \times 9.81 = 11.772$ N
Using the principle of conservation of momentum:
Change in momentum per second = Force
Change in momentum per second = 1.60 kg × velocity

Therefore, velocity = $\frac{11.772\text{ N}}{1.60\text{ kg}}$ = 7.36 m/s

11. B

Initial total mass of submarine = 3200 kg
Change in mass = 200 kg
Therefore, final total mass = 3200 kg – 200 kg = 3000 kg
g (acceleration due to gravity) = 9.81 m/s^{-2}
Change in weight (force) = 200 kg × 9.81 m/s^{-2} = 1962 N
Using Newton's second law, F = ma.
The change in weight causes the submarine to accelerate upwards. This change in weight acts as the net force.
So, 1962 N = 3000 kg × a
From this, we get the acceleration, a = 1962 N / 3000 kg = 0.654 ms^{-2}

12. A

Newton's third law states that every action has an equal and opposite reaction and the forces act on two different bodies. The weight *W* of the box is the gravitational force exerted by Earth on the box (downwards). The other force of this pair is the gravitational force exerted by the box on Earth, which acts in the opposite direction (upwards). So, the arrow representing this force is *a*.

13. B

$$F = \frac{\Delta P}{t} = \frac{mv}{t} = \frac{\rho \times \text{volume}}{t} \times V = \rho \times \text{area} \times \frac{L}{t} \times V$$

$F = \rho \times A \times V^2$ so $F = (900 \times 0.4 \times 10^{-6} \times 2.5^2)\ 400 = 0.90$ N

14. D

Force is defined by Newton's second law as the rate of change of momentum. This is mathematically expressed as: $F = \frac{\Delta p}{\Delta t}$

Where Δp is the change in momentum and Δt is the time taken for this change. Thus, the correct choice is D.

15. B

Newton's third law of motion is illustrated by equal and opposite gravitational forces on two different bodies, as in Diagram B.

16. C

Momentum = mass × velocity = 8.4×10^7 kg × 16.4 m/s = 1.3776×10^9 kg m/s.
Time to stop = momentum/force = (1.3776×10^9 kg m/s) / (920,000 N) = 1,498 s or 25 minutes.

17. C

The change in momentum (or impulse) is equal to the force applied multiplied by the time over which it's applied, i.e., Impulse = F × t.

18. A

When the system reaches static equilibrium, the upward force (tension) in the thread is equal to the weight of the 0.10 kg mass (0.10 × 9.8 = 0.98 N). After the thread is cut, this tension acts on the 0.20 kg mass as an upward force. Using F = ma, the acceleration a = F/m, which results in an upward acceleration of 4.9 m/s^2 for the 0.20 kg mass.

19. C

Newton's third law states that for every action, there is an equal and opposite reaction. This implies that the forces act on different objects, in opposite directions, and are of equal magnitude. It does not require that the forces act on objects in contact. Hence, option C is correct.

20. A

Assuming that there is no evaporation or melting, the drag force on the snowflake will be greater due to its larger surface area, which makes it encounter more air resistance. As a result, the snowflake will take more time to reach terminal velocity (maximum constant speed) compared to the raindrop. Thus, the raindrop will reach the ground before the snowflake does.

21. D

To determine the average force during the collision, we employ the formula which relates change in momentum to force and time: $F = \Delta p/\Delta t$.
Initial momentum = 0.5 kg × 12 m/s = 6 kg.m/s (towards the wall)
Final momentum after bouncing = 0.5 kg × 8 m/s = 4 kg.m/s (away from the wall)
Total change in momentum = 6 + 4 = 10 kg.m/s
Average force = Change in momentum/Time taken = 10 kg.m/s / 0.1 s = 100 N.

22. **A**

$a_{child} = a_{sledge}$

$\left(\frac{F}{m}\right)_{child} = \left(\frac{F}{m}\right)_{sledge}$

$\frac{12 - \text{friction}}{20} = \frac{12 + \text{friction}}{40}$

$2(12 - f) = 12 + f$
$3f = 12$
$f = 4$ N

23. **D**

$F = \frac{mv}{t}$ as $m = \rho v$

$F = \frac{\rho v'}{t} \times v$ as $v = A \times L$

$F = \rho \times A \times \frac{L}{t} \times v = \rho A v^2$

24. **D**

If an object moves at a constant speed in a straight line, it's not accelerating. According to Newton's first law, if there's no net force (or resultant force) acting on an object, it will maintain its state of motion. Thus, the resultant force is zero.

25. **C**

The gradient of a momentum-time graph represents the rate of change of momentum, which is the resultant force acting on the car according to Newton's second law ($F = \Delta p/\Delta t$). Therefore, the correct answer is C.

26. **C**

Block X exerts a force on block Y, but it also receives an equal and opposite reaction force from block Y according to Newton's third law. Since block Y has a smaller mass, it accelerates more. Hence, the force that block X exerts on Y is less than the applied force F due to the presence of the reaction force. Thus, the correct answer is C.

27. **C**

In air, the object experiences air resistance, causing it to reach terminal velocity. The velocity-time graph becomes a curve that flattens out as time increases. Therefore, the correct graph is C.

28. **A**

The net force on the car is $F = ma = 750$ kg × 2.0 m/s^2 = 1500 N. The driving force is 2000 N. The resistive force is 2000 N – 1500 N = 500 N or 0.50 kN. Therefore, the correct answer is A.

29. **C**

A constant resultant force produces a constant acceleration, leading to a linear increase in velocity and momentum over time. Therefore, the graph showing momentum *p* increasing linearly with time t is correct, matching option C.

30. **B**

In a gravitational field, any object with mass experiences a gravitational force, which we perceive as weight. Therefore, if the object has mass, then the field causes it to have weight, matching option B.

31. **D**

The change in momentum (Δp) is:
$\Delta p = m(v_s - v_i)$ = 0.16 kg (15m/s - (-20m/s)) = 0.16 kg × 35m/s = 5.6 kg m/s
The average force is:

$F = \frac{\Delta p}{\Delta t} = \frac{5.6\text{ kg m/s}}{1.0\text{ s}} = 5600$ N

Thus, the average force exerted by the wall on the ball is 5600 N, matching option D.

32. **B**

The forces acting on each parachute are gravity and air resistance. For both parachutes, at terminal velocity, the total force is zero. Since parachute Y has twice the mass and twice the air resistance of parachute X, their accelerations are equal.
The mass and drag force on Y are both double those one X, and so, using F = ma,
For X: $mg - R - ma_x$
for Y: $2mg - 2R = 2ma_y \rightarrow mg - R = ma_y = ma_x \rightarrow a_y = a_x$.
The acceleration of Y is therefore the same as the acceleration of X.

33. A

$F = \frac{m}{t}(v - u) = \frac{90}{60} \times 20 = 30N.$

Remember to convert the rate into kg per seconds from kg per minutes.

34. C

According to Newton's third law of motion, for every action, there is an equal and opposite reaction. If the weight of the book (the action force) is acting downward on the table, the reaction force is the table exerting an equal force upward on the book. This is represented by option C.

35. D

According to Newton's third law, every action has an equal and opposite reaction. The gravitational force that Earth exerts on the rocket has an equal and opposite force, which is the gravitational force that the rocket exerts on Earth.

36. D

Using $g = \frac{\text{Weight}}{\text{Mass}}$:

A: 6.67 ms^{-2}, B: 6 ms^{-2}, C: 10 ms^{-2}, D: 3.47 ms^{-2}. Planet D has the lowest acceleration of free fall.

37. D

The change in momentum in horizontal direction is zero.
The change in momentum in the vertical direction is:
$\Delta p_y = 2p\sin\theta$
The average force F during the collision is:

$F = \frac{\Delta p_y}{t} = \frac{2p\sin\theta}{t}$

Thus, the magnitude of the average resultant force acting on the ball during the collision is $\frac{2p\sin\theta}{t}$, which matches option D.

38. D

Conservation of momentum is not among Newtons laws of motion.

39. A

F = ma along the slope $\rightarrow$ 5g sin 30° = 5a w $\rightarrow$ a = 4.91 ms^{-2}.

distance moved $= s = \frac{1}{2}at^2 = \frac{1}{2} \times 4.91 \times 0.8^2 = 1.6m.$

40. D

kinetic energy = work done $\rightarrow$ 10 = F $\times \frac{5}{1000} \rightarrow F = 2000N$

41. B

change in momentum of R = change in momentum of S

$1 \times 10^{27} \times (1 \times 10^4 - (-1 \times 10^4)) = 1 \times 10^{30} \times \Delta v$

$2 \times 10^{31} = 1 \times 10^{30} \times \Delta v \rightarrow \Delta v = 20ms^{-1}$

42. D

The balloon accelerates from rest till it reaches the terminal velocity.

43. B

Resultant force = rate of change of momentum.
Since resultant force is increasing, the gradient of p-t graph should also increase. This is only true for option B.

44. D

Since the gun is stationary, its kinetic energy is zero. However, the kinetic energy of the bullet is not zero when the gun is fired as the bullet leaves the gun with a very high velocity.

45. C

Weight = mass x gravitational acceleration
Mass on earth = mass everywhere = 660/9.8 = 69.5 kg
Weight on mars = 69.5 x 3.71 = 257.7 N

46. D

Resultant force = (mv - mu)/Δt = [(0.2 x 14)-(0.2 x (-7))]/0.6 = 7 N

47. A

Option A is the correct statement of Newton's first law known as the law of inertia. Newton's first law states that every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force.
B is referring to the description of uniform circular motion.
C is referring to a mass leaving the circular motion with linear speed that is tangential to its circular path.
D is the statement of Newton's second law, where force = rate of change of momentum of an object.

48. C

Mass is the quantity of matter in a physical body. It is also a measure of the body's inertia, the resistance to acceleration (change of velocity) when a net force is applied.

49. A

The third law states that for every action (force) in nature there is an equal and opposite reaction. If object A exerts a force on object B, object B also exerts an equal and opposite force on object A. Hence C and D are incorrect.
The third law forces are of same type, same in magnitude, opposite in direction and act on different objects. This corresponds to A. Since weight of box is acting down on earth, earth will exert a force upwards on the box.

50. B

The third law forces are of same type, same in magnitude, opposite in direction and act on different objects. This corresponds to B. Since earth is exerting a gravitational force on moon, moon also exerts an equal but opposite gravitational force on earth.

51. B

Newton's 2nd law of motion: Force, $F = \Delta p / \Delta t$
Change in momentum, $\Delta p = F\Delta t$
Gradient of graph = $\Delta p / \Delta t$. Thus, the gradient of the graph represents the force.
The gradient of the graph should have a magnitude equal to 10 N.
For choice B, gradient = (20 – 0) / (0 – 2) = (-) 10 N

52. A

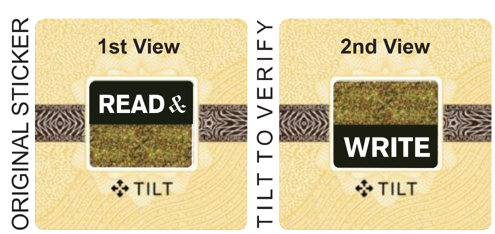
When the person applies a force F, there is a resultant acceleration a on the car. Remember that there is a resistive force R (in the opposite direction to F).
Resultant force = mass × acceleration
$F - R = ma$ ------------------- (1)
The person needs to apply a force of 2F to produce a resultant acceleration of 3a.
Resultant force = mass × acceleration
$2F - R = 3ma$ ------------------- (2)
From equation (1), $F = ma + R$. Replace F by $(ma + R)$ in equation (2).
$2(ma + R) - R = 3ma$
$R = 3ma - 2ma = ma$

53. B

The mass is a property of the body and is constant anywhere.
Mass on P = mass everywhere = 1.0 kg
Weight = mass x gravitational acceleration
Weight is directly proportional to gravitational acceleration, hence a gravitational acceleration of ten times means the weight on Q will be 10 times that on P
Weight on Q = 1 x 10 = 10 N

54. A

The emerging water has some momentum and hence exerts a force on the person. From Newton's 3rd law, the person should exert a force same in magnitude but in the opposite direction to prevent the hose-pipe from moving backwards.
$\Delta p / t = (\Delta m)v / t = (\Delta m / t)\, v$
Äm / t = rate of water being pumped = 90kg / min
1 min = 60s corresponds to 90kg of water
Rate of water being pumped = $\Delta m / t = 1.5 \text{kg s}^{-1}$
Force = $\Delta p / t = (\Delta m / t)\, v = 1.5 \times 20 = 30\text{N}$



55. A

Acceleration down an incline = $g\sin ø = 9.8 \sin(30) = 4.9 \text{ m/s}^2$

56. C

Force F = change in momentum / time = $\Delta p / t$
The speed changes from 16.4 ms^{-1} to zero (the ship stops).
Change in momentum, $\Delta p = m\Delta v = m\,(16.4 - 0)$
Time $t = \Delta p / F = (8.4\text{x}10^7 \text{ x } 16.4) / 920\,000 = 1497\text{s} = 25\text{min}$

57. D

Resultant force = (mv - mu)/Δt = m (v - u)/Δt = [55/1000 x (30-(-20))]/5 x 10^{-3} = 550 N

58. C

For an elastic collision,
Relative speed of approach (before collision) = Relative speed of separation (after collision)
Relative speed of approach = v + 0 = v
Let the speed of Y be y.
Relative speed of separation = 3v / 5 + y
Relative speed of approach = Relative speed of separation
v = 3v / 5 + y
Speed y = v – (3v/5) = 2v / 5
Kinetic energy = ½ mv^2
Kinetic energy of Y = ½ × 4m × $(2v/5)^2$ = 16 mv^2 / 50

59. B

Weight = mass x gravitational acceleration
gravitational acceleration = gradient of weight-mass graph
Gradient = (4-0)/2.5 = 1.6

60. C

Consider one steel pellet,
Initial velocity = 5.0 m s^{-1}
Final velocity = – 4.0 m s^{-1} (the direction changes)
Change in momentum Δp = mΔv = 0.6×10^{-3} × (–4.0 – 5.0) = (–) 5.4×10^{-3} Ns
This is the change in momentum of ONE steel pellet.
Rate of fall of pellets on the plate = 100 pellets per min
1 s → 100 / 60 = 1.667 pellets
In 1 second, an average of 1.667 pellets fall on the plate.
Force F = Δp / Δt (force is the change in momentum per second)
Average force = rate of change of momentum of all pellets
Average force = 1.667 × 5.4×10^{-3} = 0.0090 N

61. C

For 1-D collisions, an object with greater momentum will always impart energy and hence its velocity cannot increase. When two objects collide, the object with the higher velocity, and thus greater momentum, will transfer more energy to the slower object than vice versa. After the collision, the object with the slower initial velocity will move away with a higher velocity, and momentum, than the object with the higher initial velocity.

62. B

When descending at constant speed, air resistance = F (upwards). A constant speed means the acceleration = 0. In other words, the resultant force = 0 [since F = ma]. That is, the sum of upward forces = sum of downward forces.
W = F + U eqn 1
When ascending, if speed is the same constant speed, air resistance = F (downwards since it is ascending). Some weight of the material needs to be released for the resultant force to be zero. Let the weight to be released be R.
(W–R) + F = U eqn 2
From eqn 1,
Upthrust U = W – F eqn 3
The upthrust force has the same value throughout the motion.
Replace U from eqn 3 in eqn 1.
W – R + F = W – F
R = 2F

63. C

For Newton's third law, the two forces in each pair must be <u>the same type of force</u> and <u>act on different bodies</u>. (The forces should also be equal in magnitude and opposite in direction.)
The equal and opposite reaction force to the weight of the object is the force with which the object pulls upwards on the Earth. [C is correct].

64. D

Average force = Δp/Δt
Δp = [2 x 4 – (2 x (-2.8))] = 13.6
Force = 13.6 /150 x 10^{-3} = 91 N

65. B
F = ma
Hence acceleration is inversely proportional to mass for constant F.

66. A
Gradient of graph = $\Delta p / \Delta t$. Thus, the gradient of the graph represents the force.
Force = (500-0)/(10-0) = 50 N

67. A
Weight = mass x gravitational acceleration
Mass on earth = mass everywhere = 6/9.8 = 0.61 kg
Weight on pluto = 0.61 x 0.66 = 0.4 N

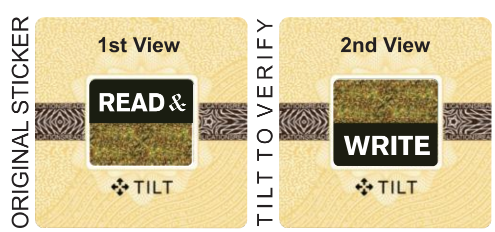
68. D
Average force = $\Delta p/\Delta t$
Δp = [8/1000 x 300 – 0] = 2.4
Force = 2.4 /100 x 10^{-6} = 24000 N

69. C
Mass flow rate (= mass / time = $\Delta m / \Delta t$) = 40 kg s^{-1}
Weight = mg = (96 × 9.81) N
The resultant vertical force on the platform is zero. So, there should be an upward force on the platform that is equal in magnitude to the weight. This upward force occurs as the momentum of the water changes (since it is flowing).
Upward force = $\Delta p / \Delta t = \Delta(mv) / \Delta t = v (\Delta m/\Delta t)$
The flow rate $\Delta m/\Delta t$ is 40 kg s^{-1}.
Upward force = 40 v
The resultant vertical force on the platform is zero.
Upward force = Weight
40 v = 96 × 9.81
Speed v = (96 × 9.81) / 40 = 23.5 = 24 ms^{-1}

70. D
The kinetic energy is converted into work done by the hammer in pushing the nail into the plank. Since both the hammer and nail come to rest after the collision, all of the KE of the hammer has become 'work done'.
Work done = Force × distance
10 = F × 5 × 10^{-3}
F = 10 / (5 × 10^{-3}) = 2000 N

71. B
force = $\Delta p / \Delta t$ according to Newton's second law.

72. C
Mass of X = M_1 and Mass of Y = M_2
Both blocks are moving with same acceleration a.
$F=(M_1 + M_2)a$
$a= F/(M_1 + M_2)$
Let Y be the force on Y,
$Y=M_2 \times a$
$Y = M_2 \times F/(M_1 + M_2)$
Since $M_1 > M_2$, $M_2/(M_1 + M_2)$ is < 1. Hence Y is < F.



73. D
Option A: Δp = Force x Δt. Total change in momentum of the ball is area under the graph between force and time. So here average force is the ratio of area under the force time graph and total time of the graph
Option B: Δp = Force x Δt. Total change in momentum of the ball is area under the graph between force and time
Option C: Here total time of contact is the total time for which force is acting on the ball which is represented on the x-axis of the graph.
Option D: Here since we do not know about the mass of ball, we can not find the acceleration.

74. A
For Newton's third law, the two forces in each pair must be <u>the same type of force</u> and <u>act on different bodies</u>. (The forces should also be equal in magnitude and opposite in direction.)
The equal and opposite reaction force to the weight of the object is the force the object pulls upwards on the Earth.

75. A

$F \times t = \Delta p$

The change in momentum is given by the impulse, i.e. average force × time or the area under the graph.

Area under graph = $\Delta p = F \times t = ½ \times 40 \times 10 = 200\ 000$ Ns

$\Delta p = m(\Delta v)$

Dividing by the mass then gives the change in speed.

Initially, the glider is at rest. i.e. initial speed = 0

$\Delta p = m(v–0) = mv$ where v is the final speed

mv = 200 000 Ns

Speed v = 200 000 / 1500 = 133 ms^{-1}

76. A

The weight of the 2.0kg mass acts downwards. So, the 2.0kg mass pulls the 8.0kg box to the right with a force (equal to its weight) of

Weight of 2.0kg mass = 2.0 (9.81) = 19.62N

The force of friction opposes motion and thus it acts to the left.

Resultant force on the system = 19.62 – 6.0 = 13.62N = ma.

It is important to note that the system consists of an 8.0kg box AND a 2.0kg mass. So, the total mass in the system is 8.0 + 2.0 = 10.0kg. So, both the box and the mass need to be accelerated.

ma = 13.62N

Acceleration a = 13.62 / 10 = 1.36 ≈1.4ms^{-2}

77. D

The average weight of an adult is 70 kg

Weight = mass x gravitational acceleration = 70 x 9.8 = 686 N. This is closest to D.

78. C

According to newton's second law, force = rate of change of momentum

79. A

From Newton's 2nd law,

Force = rate of change of momentum = $\Delta p / \Delta t = (\Delta m)v / t = (\Delta m / t)\ v$

$\Delta m / t$ = rate of water being pumped = 90kg / min

1s corresponds to 90 / 60 = 1.5kg

Rate of water being pumped = $\Delta m / t$ = 1.5kg s^{-1}

Force = $\Delta p / t = (\Delta m / t)\ v = 1.5 \times 20 = 30$N.

80. B

Resultant force on the trailer is zero during motion {since the speed is constant, resultant acceleration, and hence resultant force is zero}, so the (forward) force exerted by tractor on trailer is (= 4000/4 =) 1000 N (since one quarter of the resistance acts on the trailer). This force is equal and opposite to the force exerted on tractor by the tow-bar.

81. B

Force = rate of change of momentum = $\Delta p / \Delta t$

Gradient of graph = $\Delta p / \Delta t$. Hence the force will be the greatest where gradient is the greatest. This is at point B where the graph is steepest.

82. C

From Newton's 2nd law,

Force = rate of change of momentum = $\Delta p / \Delta t$

83. A

Resultant force = ma = 750 (2.0) = 1500N = 1.5kN

Resultant force = Driving force – Resistive force

Resistive force = Driving force – Resultant force = 2.0 – 1.5 = 0.5kN

84. D

Average force = $\Delta p/\Delta t$

$\Delta p = [12 \times 0.5 – (0.5 \times (-8))] = 10$

Force = 10 /0.10 = 100 N

85. C

Kinetic energy = ½ mv^2. So, it is conserved.

Mass is also conserved as it remains the same.

Speed (which is a scalar – the choice is not 'velocity') is also conserved as it remains v.

The property which is not conserved here is the momentum of the object. Momentum is a vector quantity. Initial momentum = mv. Final momentum = - mv. Note that even if the momentum of the object is not conserved, the momentum of the whole system should be conserved. So, the key word in the question is 'property of the object', not the whole system.

86. B

$\Delta p = mv - mu = 20000(30-6) = 480000$ Ns

Force = rate of change of momentum = $\Delta p / \Delta t = 480000/300 = 1600$N

87. A

The gravitational force acts on the 1.0kg mass, causing an acceleration of $9.81ms^{-2}$.
Weight of 1.0kg box = 1 x 9.81 = 9.81N
But as the 1.0kg mass moves, the 2.0kg also undergoes motion. Therefore, considering the whole system, a force of 9.81N is acting on a total mass of (2.0 + 1.0 =) 3.0kg.
The resultant acceleration, 'a' on this total mass can be obtained as follows

$3a = 9.81 \Rightarrow a = 9.81 / 3 = 3.27ms^{-2}$

$v^2 = u^2 + 2as = 0 + 2 (3.27) (0.5)$

Speed, $v = \sqrt{(2 \times 3.27 \times 0.5)} = 1.8ms^{-1}$

4.2: Non-uniform motion

1. **B**
When an object reaches terminal velocity, the downward force of gravity is balanced by the upward force of air resistance, resulting in no net force. Thus, the acceleration decreases to zero because the forces are in equilibrium, correctly reflected in option B.
2. **D**
Graph D shows an object accelerating initially (due to gravity) and then moving at a constant speed, indicative of reaching terminal velocity - consistent with long-distance free fall in Earth's atmosphere.
3. **D**
The cyclist's maximum speed increases when traveling downhill due to the additional gravitational force, resulting in non-uniform motion. This effect is more significant than other options like wind resistance or changes in body position.
4. **B**
The stone (S) has a higher density than the foam rubber ball (R), so it reaches terminal velocity faster due to greater gravitational force and lower air resistance effect. Hence, the correct graph is B, showing S reaching a higher terminal velocity earlier than R.
5. **A**
When a skydiver opens his parachute, the increased air resistance causes a significant deceleration. Therefore, the direction of the velocity remains downwards, but the magnitude of the velocity decreases.
6. **A**
As a body falls under gravity with air resistance, its acceleration decreases because of the increasing force of air resistance. The graph shows quantity P decreasing as quantity Q increases, which matches the relationship between acceleration and the force of air resistance. Thus, P represents acceleration and Q represents the force of air resistance.
7. **C**
As height increases, G.P.E increases.
8. **C**
When velocity is constant (acceleration = 0), hence resultant force = 0.
$0 = mg - kv^2$
$kv^2 = mg$
$v = \sqrt{mg/k}$
9. **D**
When velocity is constant (acceleration = 0), hence resultant force = 0. Frictional force is always parallel to the surface and acts opposite to the direction of motion of the object. Since the box is moving down the board, the frictional force must act in a direction up the board.
10. **B**
When velocity is constant (acceleration = 0), hence resultant force = 0.
$0 = mg - kv^2$
$v = \sqrt{mg/k}$

When m is 0, v is also zero. This is only true for B and D. The only graph that corresponds to that of a square root is B.

11. D

The mass measured on the scale is due to the normal force acting on the scale.
For an elevator moving downward:
Normal = mg + ma
For an elevator moving upward:
Normal = mg – ma (apparent weight is less than mg by ma)
Since the mass of the person has decreased, the elevator must be moving upwards.
Hence A and B are incorrect. D is incorrect since if the person were travelling at constant speed, acceleration would be 0 and hence Normal = mg. The apparent weight on the scales would be equal to the normal weight of the person i.e., 60 kg. Since this is not the case here (apparent weight is 58 kg), option C is wrong. This only leaves D.

12. C

As the object falls through air, the force of air resistance on it increases and hence the resultant force on it and therefore its acceleration decreases until it becomes 0 (terminal velocity reached). This corresponds to 3. As the object falls, due to acceleration, its velocity will increase until it reaches a constant terminal velocity (acceleration =0). This corresponds to 1. Acceleration means the speed of the object is increasing with time. Though the acceleration of the object decreases as it falls, its speed is still increasing albeit at a lower rate. Speed would only decrease if the object was decelerating.

13. D

As the ball is released from rest, its weight causes a downward acceleration. Since the ball is accelerating, its speed will increase with time. Since the effects of air resistance are appreciable, as the ball falls, there is an upward resistive force due to air resistance on the ball. Air resistance increases with speed. So, as the speed of the ball increases (due to its resultant downward acceleration), the force of air resistance increases. Hence the resultant force on the ball decreases until it becomes zero; at this point, terminal speed has been reached and the ball no longer accelerates and just falls at a constant speed. Hence initially the speed of the ball increases as it accelerates until it reaches terminal velocity and speed becomes constant. S-t graph of increasing speed is an upward curve. This is true for A and B. S-t graph of constant speed is a straight line. This only corresponds to D.

14. C

Force = $m(v - u)/\Delta t = 2.5 \times (12-3)/15 = 1.5$ N

15. A

In a closed system, momentum is conserved. Hence change in momentum of the orbiter = change in momentum of the lander
Change in momentum of lander = $m\Delta v = 100 \times 3 = 300$
Change in momentum of orbiter = $170 \times \Delta v = 300 \Rightarrow \Delta v = 1.8$ m/s

16. D

Resultant force = mass x acceleration.
Since resultant force = 0, acceleration must be 0 as well. When acceleration is zero, there is no change in velocity and hence the snowflake travels at a constant velocity.

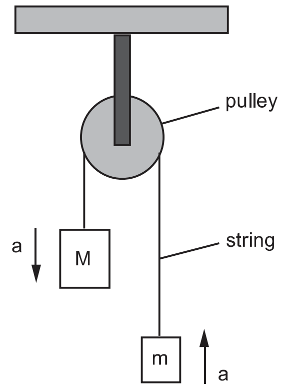
17. C

As the stone is dropped, its weight causes a downward acceleration and its speed will increase with time. Since the effects of air resistance are appreciable, as the stone falls, there is an upward resistive force due to air resistance on it. Air resistance increases with speed. So, as the speed of the stone increases (due to its resultant downward acceleration), the force of air resistance increases. Hence the resultant force on it decreases until it becomes zero; at this point, terminal speed has been reached and the stone no longer accelerates and just falls at a constant speed. Hence initially the speed of the ball increases as it accelerates until it reaches terminal velocity and speed becomes constant. S-t graph of increasing speed is an upward curve. This is true for A and B. S-t graph of constant speed is a straight line. This only corresponds to B and C. Since the mass of the second stone is smaller, its weight will be lesser (will become equal to force of air resistance quicker), and it will reach the terminal velocity earlier than the first stone. Since both stones have same initial acceleration (g = 9.8), but the second stones travels for a shorter time before reaching terminal velocity, the second stone's terminal velocity will be smaller than that of first stone and the gradient of the straight part of the graph will be smaller for it. This is true for C.

18. C

Force = rate of change of momentum = $\Delta p / \Delta t$

19. B



For mass m, the forces are given as
T - mg = ma ...... (1)
Similarly, for mass M, the forces are given as
Mg - T=Ma ...... (2)
From equation (1), we have
T=mg + ma ...... (3)
Substituting equation (3) in (2) we get
Mg - mg - ma = Ma
g(M - m) = a(M + m)
a = (M - m)g/(M + m)

20. B

Since the stone is projected in a vacuum, there is no air. Therefore, there is no air resistance. The force of gravity acts downwards. So, at any point along the path, there will be a force downwards – this will along XV in the diagram given. As this is in a vacuum, there is no air resistance, nor any other forms of friction (forces that oppose motion). XT represents the direction of motion of the stone at a point on the path. XH represents the horizontal component of the motion (speed).

21. A

$v^2 = u^2 + 2as$
$0^2 = 2^2 + 2a(30) \Rightarrow a = 0.067\ m/s^2$
F = ma = 150/1000 x 0.067 = 0.010 N

22. A

As the ball is released from rest, its weight causes a downward acceleration on it. Since the effects of air resistance are appreciable, as the ball falls, there is an upward resistive force due to air resistance on the ball. Thus, the resultant downward acceleration of the ball decreases with time. Air resistance increases with speed. So, as the speed of the ball increases (due to its resultant downward acceleration), the effects of air resistance increases. On the graph, this is indicated by the non-linear decrease of the line. The resultant acceleration on the ball would decrease until it becomes zero at some point – terminal speed has been reached.

23. D

The gradient of speed-time graph = acceleration
Acceleration is directly proportional to resultant force. Since the gradient of graph is lesser at Y than at X, the acceleration and hence resultant force is smaller at Y than at X.

24. B

The force F is due to air resistance. Air resistance opposes motion. Air resistance increases with speed. At time t = 0, air resistance is zero since the sky diver is initially in a stationary balloon. Her speed is also initially zero. [D is incorrect]. As the sky diver falls, her speed increases from zero. Comparing her speed at earlier values of t to the speed at greater value of t, it is obvious that the speed during the earlier stage is less than after. Air resistance increases with speed. So, during the first few seconds, the increase in air resistance is relatively smaller compared to later time. That is, the rate of increase of air resistance is not constant (gradient of the graph shown cannot be constant – so, from time = o to time = T, the graph is not a straight line). [A is incorrect]. The sky diver falls due to the acceleration due to gravity. Therefore, until terminal velocity is reached, the speed keeps on increasing. At the terminal velocity, the resultant force on the sky diver is zero since air resistance equals force of gravity (weight). Since the weight of the sky diver is constant, air resistance should also be constant from time T and beyond. Air resistance cannot keep on increasing after time T. [C is incorrect]

4.3: Linear momentum and its conservation

1. **D**
For a perfectly elastic collision between two objects of equal mass, the objects will exchange velocities. Therefore, after the collision, ball P will have the velocity of ball Q, and ball Q will have the velocity of ball P. So, ball P will move to the left with a velocity of 0.50 m/s, and ball Q will move to the right with a velocity of 1.30 m/s. Therefore, the correct answer is D.
2. **C**
Initially: $m_1 = m$, $m_2 = 2m$, $u_1 = 2v$, $u_2 = -v$
after collision: $v_1 = -v$
using conservation of linear momentum:
$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
$2mv - 2mv = -mv + 2mv_2$
$v_2 = v/2$
Initial kinetic energy = $\frac{1}{2} m(2v)^2 + \frac{1}{2} (2m)v^2 = 3mv^2$
Final kinetic energy = $\frac{1}{2} mv^2 + \frac{1}{2} (2m)(v/2)^2 = 3/4\ mv^2$
loss in Kinetic Energy = Initial KE – Final KE $= 9/4\ mv^2$
3. **B**
The average force exerted during the collision is calculated by using the change in momentum and the time of impact. The change in momentum is 6 kg m / s (since the ball reverses direction), and with an impact time of 0.1 s, the average force is $\frac{6\text{kg m/s}}{0.1\text{s}} = 60$ N.
4. **B**
For the two objects to come to a complete stop after colliding and sticking together, their initial momenta must be equal and opposite, thus canceling each other out to result in zero total momentum. This satisfies the principle of conservation of momentum, where the total momentum before the collision equals the total momentum after the collision, which is zero if they are stationary.
5. **C**
To find the value of *v* for Object Y after the collision, we'll use the principle of conservation of momentum.
$m_xv_{x1} + m_yv_{y1} = m_xv_{x2} + m_yv_{y2}$
$0.30 \times 3.0 + 0.50 \times 0 = 0.30 \times 2.0 \cos(60°) + 0.50 \times v \cos(41°)$
$0.9 = 0.30 + 0.50 \times v \times 0.7547$
$v = \frac{0.6}{0.37735} \approx 1.59$ m / s. Rounded to one decimal, $v \approx 1.6$ m / s.
6. **A**
For an elastic collision, momentum is conserved. The initial momentum is the sum of the momenta of balls X and Y: μX and μY. After the collision, the momentum is μX and μY. So, the equation μX + μY = μX + μY represents conservation of momentum.
7. **D**
During the elastic collision, the object of mass m rebounds with $\frac{1}{4}$ of its kinetic energy, retaining $\frac{1}{2}$ its initial speed. Applying conservation of momentum:
$mu = m\left(-\frac{u}{2}\right) + 4m \cdot v$ and solving for v gives $v = \frac{3u}{8}$.
8. **B**
Calculate the initial momentum before the collision: $p_i = m \times v = 0.20$ kg × 0.40 m/s = 0.080 kg m/s
Calculate the final momentum after the collision: $p_f = m \times v_f = 0.20$ kg × 0.30 m/s = 0.060 kg m/s
Since the direction changes by 90°, use the Pythagorean theorem to find the magnitude of the change in momentum:
$\Delta p = \sqrt{(0.080)^2 + (0.060)^2} = \sqrt{0.0064 + 0.0036} = \sqrt{0.0100} = 0.10$ kg m/s. Therefore, the correct answer is B.

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9. C

In elastic collision K·E before collision is equal to K·E after collision.

$$\frac{1}{2}mv^2 + 0 = \frac{1}{2}m\left(\frac{3v}{5}\right)^2 + K{\cdot}E_y$$

$$K{\cdot}E_y = \frac{1}{2}mv^2 - \frac{9mv^2}{50} = \frac{16}{50}mv^2$$

10. C

In perfectly elastic collisions, the speed of approach is equal to the speed of separation. Other statements are either always true or conditionally true, making option C the most fitting answer for collisions.

11. D

Speed of approach = - Speed of seperation

$6 - 0 = -(2 - V)$

$V = 8$ cm/s

12. B

The steel ball transfers more momentum to the steel block compared to the wooden block where it embeds, resulting in the steel block traveling faster than the wooden block after the impact.

13. C

Linear momentum is defined as the product of an object's mass and its velocity. Thus, the correct definition is "product of velocity and mass".

14. B

Speed of approach = −Speed of seperation

$5 - (-15) = -(v_X - 7)$

$20 = -v_X + 7$

$v_X = -13$ m/s

So, 13 m/s towards left.

15. D

The principle of conservation of momentum states that if no external forces act on a system of interacting objects, the total momentum of the system remains constant. This is a fundamental principle in physics and is valid irrespective of the nature of interactions between objects, whether they are elastic, inelastic, or explosive. Thus, option D correctly encapsulates the conservation of momentum principle.

16. A

Momentum before collision = Momentum after collision

$80(2) - 40(1) = 80(0.8) + 40v$

$v = 1.4\ ms^{-1}$

Relative speed = Higher speed - Lower speed

(if object move same direction)

Relative speed = 1.4 - 0.8 = 0.6 ms^{-1}

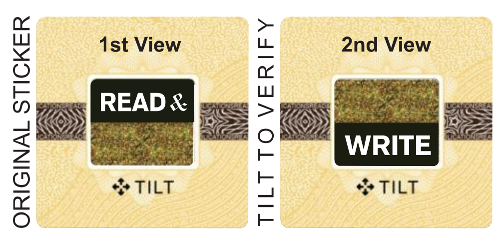
17. D

Momentum before collision = Momentum after collision

$2m \times v = m \times v' + m \times 0$

$v' = 2v$

So, Kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2} \times m(2v)^2 = 2mv^2$



18. D

In an elastic collision initial K.E. = final K.E. This is clearly true for D.

19. A

For elastic collisions, velocity of separation = velocity of approach. This is true for A:

$$u - (-u) = \frac{5u}{3} - \left(-\frac{u}{3}\right) = 2u$$

20. D

To find the velocity v of Q after the collision, we use the conservation of momentum along the direction of the initial motion of P:

320 = 180 cos55° + v cos34°

320 = 180 × 0.5736 + v × 0.8290

320 = 103.248 + 0.829 v

216.752 = 0.829 v

$v = \frac{216.752}{0.829} \approx 261.49\ ms^{-1} \approx 260\ ms^{-1}$

21. C

In an inelastic collision, kinetic energy is not conserved as some of it is converted to other forms of energy like heat or sound. However, total energy and linear momentum are conserved due to the laws of conservation of energy and momentum. Therefore, the correct answer is C.

22. B

Momentum is conserved. If the rock moves away from the star (reversing direction), the spacecraft must move towards the star to conserve momentum. Both moving away from the star (option B) violates conservation of momentum.

23. A

Using conservation of momentum in the horizontal plane, the initial momentum is zero. The total momentum in each direction must sum to zero.

(15 g × v) = (10 g × 300 m/s)

15 v = 3000

v = 200 m/s

Thus, the speed v of fragment X is 200 m/s, matching option A.

24. C

In elastic collisions kinetic energy is conserved. For C, K.E. is 66m J before and 57 m J after collision.

25. C

Conservation of linear momentum implies that for the first equation $Mv = mu \rightarrow v = \frac{m}{M}u$.

For the second collision, $2Mv_2 = 2m \times 2u = 4mu \rightarrow v_2 = 2\frac{m}{M}u = 2v$.

26. B

conservation of momentum implies $4 \times 2 + 1 \times 4 = v \times (2 + 4) \rightarrow v = 2ms^{-1}$

Change in K.E.: $\frac{1}{2} \times 2 \times 4^2 + \frac{1}{2} \times 4 \times 1^2 - \frac{1}{2} \times 6 \times 2^2 = 6J$

27. D

Initial momentum = final momentum $\rightarrow 5um + u5m = (m + 5m)\,v \rightarrow 10mu = 6mu \rightarrow v = \frac{10}{6}u$

28. D

In elastic collisions, kinetic energy is conserved. Hence KE before collision = KE after collision

$\frac{1}{2} m_1u_1^2 + \frac{1}{2} m_2u_2^2 = \frac{1}{2} m_1v_1^2 + \frac{1}{2} m_2v_2^2$

$m_1u_1^2 - m_1v_1^2 = m_2v_2^2 - m_2u_2^2$. Hence A is correct.

Momentum is always conserved hence Momentum before collision = Momentum after collision

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$m_1u_1 - m_1v_1 = m_2v_2 - m_2u_2$

$m_1(u_1 - v_1) = m_2(v_2 - u_2)$. Hence B is correct.

For elastic collisions, relative seed of approach and separation are equal in magnitude but opposite in sign, hence:

$U_2 - u_1 = -(v_2 - v_1)$

$U_2 + v_2 = v_1 + u_1$. Hence C is also correct. This only leaves D.

29. D

For a head-on elastic collision of a moving object with a stationary object of equal mass, the projectile will come to rest and the target will move off with equal velocity. For a perfectly elastic collision, both momentum and energy are conserved.

Before collision, Sum of momentum, p = mv + 0 = mv and Total kinetic energy = $\frac{1}{2} mv^2$

Consider choice D,

Sum of momentum, p = m(0) + mv = mv and Total kinetic energy = $\frac{1}{2} mv^2$

Both momentum and energy are conserved. Hence choice D is correct.

30. B

For elastic collisions, relative seed of approach and separation are equal in magnitude but opposite in sign, hence:

$U_y - u_x = -(v_y - v_x)$

12-20 = - (v - 10)

V = 18 m/s

31. C

Perfectly elastic collisions have both the momentum and kinetic energy of the system conserved. Total kinetic energy before the collision (1.188J) must be the same as the total kinetic energy after the collision. Only C satisfies this condition.

32. D

For elastic collisions, relative seed of approach and separation are equal in magnitude but opposite in sign, hence the collision must be elastic. In elastic collisions, kinetic energy is conserved. Hence KE before collision = KE after collision.

33. C

Momentum is always conserved hence

Momentum before collision = Momentum after collision

Hence the horizontal component of momentum before collision = Hence the horizontal component of momentum after collision

Hence the vertical component of momentum before collision = Hence the vertical component of momentum after collision

For option C, the vertical component of momentum before collision = 0, but the vertical component of momentum after collision is non-zero. Hence it does not satisfy conservation of momentum.

34. D

Since the collision is elastic, after colliding with the large wall, the atom will rebound with velocity = -v.

$\Delta p = mv - mu = mv - (-mv) = 2mv$

35. B

For elastic collisions, relative seed of approach and separation are equal in magnitude but opposite in sign, hence: Considering right to be positive and left to be negative:

$U_y - u_x = -(v_y - v_x)$

$-15-5 = -(7 - v_x)$

$v_x = -13$ m/s

36. B

For elastic collisions, relative seed of approach and separation are equal in magnitude but opposite in sign.

37. D

For elastic collision, both the momentum and kinetic energy are conserved.

Let mass of 1 sphere = m

Before collision,

Momentum = mv

Kinetic energy = $\frac{1}{2} mv^2$

After collision,

For A, momentum is conserved.

B is an impossible case since it would imply that sphere Y does not exist (even though momentum is conserved, this is physically impossible).

For C, sum of (magnitude of) momentum after collision is mv (but the spheres moves in opposite directions).

For D, momentum is conserved

If the speeds of both spheres become ½ v [as suggested by A and C],

Sum of Kinetic energies after collision = $\frac{1}{2} m(v/2)^2 + \frac{1}{2} m(v/2)^2 = mv^2/4$

Kinetic energy is not conserved in these 2 cases (A and C).

Only choice D will have both the momentum and kinetic energy conserved.

38. D

The total momentum of a system of interacting objects remains constant regardless of forces between the objects as long as no external forces act on the system.

39. A

$KE = p^2/2m$

$\Delta KE = p_2^2/2m - p_1^2/2m$

40. A

Momentum before the collision is = m x (-2v) + 3m x v = mv
After the collision the the trucks stick together so the total mass becomes 4m and the combined trucks move at an unknown speed of v_{after}
Momentum after =$4mv_{after}$
From conservation of momentum:
$mv = 4mv_{after} \Rightarrow v_{after} = 0.25v$

41. B

In elastic collisions, kinetic energy is conserved. Hence
KE before collision = KE after collision
KE before collision = $\frac{1}{2} mv^2 + \frac{1}{2} m(-v)^2 = mv^2$
Hence KE after collision should also be mv^2

42. C

Momentum is always conserved hence
Momentum before collision = Momentum after collision
Hence the horizontal component of momentum before collision = Hence the horizontal component of momentum after collision = 0.50 x 0.2 = 1
Hence the vertical component of momentum before collision = Hence the vertical component of momentum after collision = 0.3 x 0.4 = 1.2
Angle = $\tan^{-1}$(vertical/horizontal) = $\tan^{-1}(1.2/1) = 50°$

43. D

The total momentum of a system of interacting objects remains constant regardless of forces between the objects as long as no external forces act on the system.

44. C

Linear Momentum and total energy are always conserved in all collisions, however. Kinetic energy is only conserved in elastic collisions and not in inelastic collisions.

45. D

For elastic collisions, relative seed of approach and separation are equal in magnitude but opposite in sign, hence:
Considering right to be positive and left to be negative:
$U_y - u_x = -(v_y - v_x)$
$0 - 6 = -(v_y - 2)$
$v_y = 8$

46. B

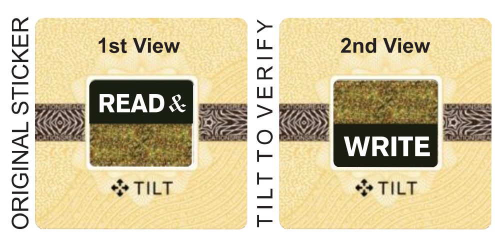
Resultant force = (mv - mu)/Δt = [(0.2 x 14) - (0.2 x (-7))]/0.6 = 7 N

47. A

Let the sphere on the back be sphere 1 and the front sphere be sphere 2.
For elastic collisions, relative seed of approach and separation are equal in magnitude but opposite in sign, hence:
$U_2 - u_1 = -(v_2 - v_1)$
Consider A:
$-5 - 2 \neq -(-2 + 5)$
Hence A is inelastic

48. B

The momentum before the explosion is zero as the firework was stationary. Momentum is a vector quantity, so we need to consider the directions. The momentum vector can be broken down into 2 components: horizontal and vertical.
Consider the vertical components:
Downward momentum = 100 × 8 = 800 g ms^{-1}
Sum of upward momentum = $50v_1 \sin 60° + 50v_2 \sin 60°$
Sum of upward momentum = downward momentum
$50v_1 \sin 60° + 50v_2 \sin 60° = 800$
$v_1 + v_2 = 18.48$ eqn (1)
Consider the horizontal components,
$50 \times v_1 \cos 60° = 50 \times v_2 \cos 60°$
$v_1 = v_2$
So, the speeds v_1 and v_2 are equal. Consider equation (1) again,
$v_1 + v_1 = 18.48$ (since $v_1 = v_2$)
Speed $v_1 = 18.48 / 2 = 9.24$ m s^{-1}



49. C

Force x $\Delta t = \Delta p$
$25 \times 0.02 = \Delta p$
$\Delta p = 0.5$
$\Delta p = p_2 - p_1$
Considering downward as positive and upward as negative, $\Delta p = p_2 - (-p_1)$
For option C $\Rightarrow \Delta p = 0.20 - (-0.30) = 0.50$
Option B is wrong even though ?0?p = 0.50 for it as well; momentum after the collision cannot increase since that would mean the ball would have gained momentum from a stationary object which is impossible.

50. A

Linear Momentum and total energy are always conserved in all collisions, however. Kinetic energy is only conserved in elastic collisions and not in inelastic collisions.

51. A

For any collision in a closed system, the law of conservation of momentum applies, i.e. the sum of momentum before collision is equal to the sum of momentum after collision.
Momentum = mv
Total momentum before collision = 2(4) + 4(1) = 12Ns
After collision, both trolleys move together (with the same speed v). So, the total mass = 2 + 4 = 6kg. The sum of momentum after collision should be equal to the momentum of collision.
$(2+4)v = 12$
Speed $v = 12 / 6 = 2ms^{-1}$
Kinetic Energy = $\frac{1}{2} mv^2 = \frac{1}{2} (6)(2^2) = 12J$

52. D

Momentum is always conserved hence
Momentum before collision = Momentum after collision
Hence the horizontal component of momentum before collision = Hence the horizontal component of momentum after collision

$\Rightarrow$ mu = mvcos30 + MVForce x $\Delta t = \Delta p$
$25 \times 0.02 = \Delta p$
$\Delta p = 0.5$
$\Delta p = p_2 - p_1$
Considering downward as positive and upward as negative, $\Delta p = p_2 - (-p_1)$
For option C $\Rightarrow \Delta p = 0.20 - (-0.30) = 0.50$
Option B is wrong even though ?0?p = 0.50 for it as well; momentum after the collision cannot increase since that would mean the ball would have gained momentum from a stationary object which is impossible.cos40

Hence the vertical component of momentum before collision = Hence the vertical component of momentum after collision

$\Rightarrow$ 0 = mvsin30 + (-MVsin40)
$\Rightarrow$ MVsin40 = mvsin30

mu = MV + mv is incorrect since momentum is a vector quantity and vectors in different directions cannot be simply added and subtracted like scalars.

53. D

For elastic collisions, relative seed of approach and separation are equal in magnitude but opposite in sign, hence:
$U_2 – u_1 = -(v_2 - v_1)$
Considering right as positive, and left as negative:
$-U_2 – u_1 = -(v_2 - v_1)$
$U_2 + u_1 = v_2 - v_1$

54. A

Let the mass of 1 trolley = M
From the conservation of momentum, the sum of momentum before collision should be equal to the sum of momentum after collision.
Sum of momentum before collision = M(60) + M(-30) = 30M
After collision, momentum = 2M(v)
2Mv = 30M
Final speed, $v = 15cms^{-1}$

55. A

Linear Momentum and total energy are always conserved in all collisions, however. Kinetic energy is only conserved in elastic collisions and not in inelastic collisions.

56. B

From the conservation of momentum, Sum of momentum before collision = Sum of momentum after collision.
Sum of momentum before collision = mu + 0 = mu
After collision,
Momentum of particle m = mu / 2 at an angle â below the horizontal
Momentum of particle M = Mu / 3 at an angle á above the horizontal
mu = Sum of momentum after collision. This is true for B where adding mu / 2 and Mu / 3 by head-to-tail rule gives resultant vector mu.
Option A: The momenta are at the wrong angles. [incorrect]
Option C: wrong angles + the negative of the momentum vectors have been taken (the direction of the vectors are opposite from what they should be) [incorrect]
Option D: the negative of the momentum vectors have been taken [incorrect]

57. C

Momentum is a vector quantity and we need to consider the direction.
Since the objects are moving in opposite direction, one of them will have a negative value.
Sum of momentum before collision = mv – mv = 0
Kinetic energy is a scalar quantity and so, the direction of motion does not matter.
Sum of KE before collision = $\frac{1}{2} mv^2 + \frac{1}{2} mv^2 = mv^2$
Momentum is always conserved.
Sum of momentum after collision = Sum of momentum before collision = 0
Giving the speed after collision, $v_f = 0$
That is, the objects do not move after the collision.
KE after collision = 0
Loss in KE = $mv^2 - 0 = mv^2$

58. D

Linear Momentum and total energy are always conserved in all collisions.

59. C

For elastic collisions, relative speed of approach and separation are equal in magnitude but opposite in sign, hence:
$U_y - u_x = -(v_y - v_x)$
For option C:
Considering right as positive, and left as negative:
$-2 - 4 = -(4 - (-2))$
$-6 = -6$
Hence option C shows an elastic collision.

60. D

For an elastic collision,
Relative speed of approach = Relative speed of separation
Since the masses are moving towards each other initially, they are 'approaching'.
Relative speed of approach = 50 + 30 = 80 cm s^{-1}
The relative speed of separation should also be 80 cm s^{-1}.
A and C are incorrect since their relative speed is 20 cm s^{-1}.
B is incorrect since the relative speed is zero.
For choice D, mass X is moving to the left while mass Y is moving to the right – so they are separating.
Relative speed of separation = 30 + 50 = 80 cm s^{-1}

61. D

Linear Momentum and total energy are always conserved in all collisions; however, kinetic energy is only conserved in elastic collisions and not in inelastic collisions.

62. D

If two objects stick together after a collision, the collision is inelastic. Since it is an example of inelastic collision. It is known that
(1) Momentum will conserved in any type of collision.
(2) Some of the kinetic energy is lost due to deformation of colliding bodies in inelastic collision.

63. C

For an elastic collision, energy is conserved. [B is incorrect]. For any collision, momentum is always conserved. Momentum of molecule before collision = mv
Thus, after hitting the wall, the molecule should still have the same amount of momentum. However, the molecule would move in the opposite direction after hitting the wall. Since momentum is a vector quantity,

we need to account for this change in sign. Thus, Momentum of molecules after collision = – mv
Change in momentum = final momentum – initial molecule
Change in momentum = (– mv) – mv = (–) 2mv
For the change in momentum, the sign may be neglected.

64. C
The total momentum of a system of interacting objects remains constant regardless of forces between the objects.

65. C
The Principle of the Conservation of Momentum states that: if objects collide, the total momentum before the collision is the same as the total momentum after the collision (provided that no external forces - for example, friction - act on the system). Hence option A is wrong. Since the collision is inelastic, kinetic energy will not be conserved (some energy will be lost). Hence the kinetic energy before collision will be lesser than the kinetic energy after the collision. This corresponds to C. Option B is wrong since kinetic energy cannot be increased after the collision since that would mean energy had been created during the collision. Option D would be correct if the collision was elastic.

66. C
The Principle of the Conservation of Momentum states that: if objects collide, the total momentum before the collision is the same as the total momentum after the collision (provided that no external forces - for example, friction - act on the system). The total momentum of a system of interacting objects remains constant regardless of forces between the objects (no external forces).

67. B
In an inelastic collision, kinetic energy is not conserved.
Before collision,
Kinetic energy, KE = $\frac{1}{2} mv^2 + 0 = \frac{1}{2}(4.0)(3)^2 = 18J$ [C and D are incorrect]
Since collision is inelastic, kinetic energy is less than 18J after collision.

68. C
Total Kinetic Energy before collision = $\frac{1}{2}(5000)(2)^2 + \frac{1}{2}(5000)(1)^2 = 12500J$
From the conservation of momentum, the sum of momentum before collision is equal to the sum of momentum after collision. Let the final speed after collision = v
Take the direction towards the right as the positive direction.
5000(2) + 5000(-1) = 10000v
Speed, v = 5000/10000 = $0.5ms^{-1}$
Kinetic Energy after collision = $\frac{1}{2}(10000)(0.5)^2 = 1250J$
Kinetic Energy lost = 12500 – 1250 = 11 250J

69. C
From the conservation of momentum, the sum of momentum before the explosion should be equal to the sum of momentum after the explosion. Before explosion, the body was stationary. So, its momentum is zero.
Momentum of component 2m + Momentum of component m = 0
Therefore, the magnitudes of momentum of the components are equal.
Let the velocity of component of mass 2m be v.
Magnitude of momentum of component 2m = Magnitude of momentum of component m
(2m) v = m (velocity)
Velocity of component of mass m = 2mv / m = 2v
Kinetic energy = ½ (mass) $(\text{velocity})^2$
$X = 0.5 (m) (2v)^2 = 2mv^2$
$Y = 0.5 (2m) (v)^2 = mv^2$
Ratio X / Y = 2

70. C
For any closed system, the total momentum before emission (or collision) equals the total momentum after the emission (or collision). This is the law of conservation of momentum and it applies for any closed system. If some energy is lost in the system, the total energy after emission can be different than what it was before emission, but momentum is always conserved. [C is correct]

71. B
For an elastic collision:
Relative speed of approach (before collision) = Relative speed of separation (after collision)

72. B
If two objects stick together after a collision, the collision is inelastic. Since it is an example of inelastic collision . It is known that

(1) Momentum will conserved in any type of collision.
(2) Some of the kinetic energy is lost due to deformation of colliding bodies in inelastic collision.

73. A

Sum of momentum before collision = $(10\times10^{-3} \times 250) + (100\times10^{-3} \times 0) = (10\times10^{-3} \times 250)$
After collision, the pellet is embedded into the block. Both can now be considered as a single body of (100+10 =) 110 g. Let the speed with which they move = v.
Momentum after collision = $(100+10) \times10^{-3} \times v$
Sum of momentum before collision = Sum of momentum of collision
$(10\times10^{-3} \times 250) = (100+10) \times10^{-3} \times v$
Speed v = (10 × 250) / 110 = 22.7 = 23 m s^{-1}

74. D

From the law of conservation of momentum, the sum of momentum before collision should be equal to the sum of momentum after collision.
Sum of momentum before collision: 2.0 (3.0) + 1.0 (0) = 6.0 Ns
Let the speed at which the masses move after collision be v.
Sum of momentum after collision = (2.0 + 1.0)v = 3.0v Ns
From the law of conservation of momentum,
3v = 6
Speed v = 6 / 3 = 2.0 ms^{-1}
Kinetic energy, KE = ½ mv^2
Sum of KE before collision = 0.5 (2.0) (3.0^2) + 0 = 9.0 J
Sum of KE after collision = 0.5 (3.0) (2.0^2) = 6.0 J
KE lost = 9 – 6 = 3 J

75. D

In elastic collisions, kinetic energy is conserved. Hence
KE before collision = KE after collision
KE before collision = ½ mv^2 + ½ $m(-v)^2 = mv^2$
Hence KE after collision should also be mv^2

76. B

Nucleus is initially stationary, so its speed is zero. Its momentum (p = mv) is also zero initially. The nucleus contains an amount of A nucleons.
Nucleus decays by emitting proton with speed v to form new nucleus with speed u.
Number of nucleons in new nucleus = A – 1
Let the mass of 1 nucleon = m
<u>After decay</u>,
Momentum of proton = mv {the proton is a nucleon}
Momentum of new nucleus = (A – 1)m(–u)
{negative is taken for the speed because the new nucleus and the proton travel in opposite direction. The direction of motion of the proton is taken as positive [v is taken as positive], so u should be taken as negative.}
Total momentum after decay = mv – (A – 1)mu
From the conservation of momentum,
Sum of Momentum before decay = Sum of Momentum after decay
$0 = mv - (A - 1)mu \Rightarrow v = (A - 1)u$

77. A

For a head-on elastic collision of a moving object with a stationary object of equal mass, the projectile will come to rest and the target will move off with equal velocity.

78. B

Momentum is conserved hence:
Momentum before collision = momentum after collision
For B:
2mu + m(-u) = 2m x (-u/6) + m x 2/3u
$mu \neq mu/3$
Hence B is incorrect since momentum before and after collision is not the same.

79. B

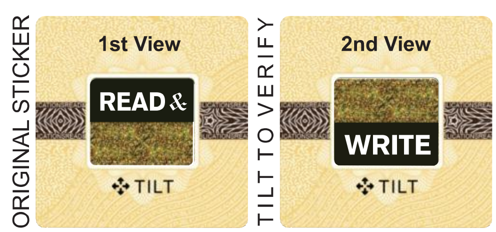
Linear Momentum and total energy are always conserved in all collisions; however, Kinetic energy is only conserved in elastic collisions and not in inelastic collisions.

80. B

Force = $\Delta p/\Delta t$ = (400 - 100)/(5.5 - 4) = 200 N

4.4: Multiple Topics

1. **D**
Since the man is standing in the lift, there is a contact (upward) force by the lift on the man. So, there are 2 forces on the man: his weight (downward) and the contact force (upward).
Since the lift (and the man) is accelerating downwards, the resultant force on the man is downwards. This resultant force is the force exerted by the man on the floor.
Resultant force = Weight – Contact force
So, the resultant force is less than the weight.
Choice A: The resultant force is equal to the weight when there is no contact force. This can occur when the man is not touching the floor.
Choice B and C: From Newton's third law, these 2 forces are equal and opposite. If choice C was correct, the man would lose contact with the floor.
2. **A**
Force X which starts high and drops to zero is likely the air resistance decreasing as speed drops, while Force Y which remains constant could be the weight of the ball, constant throughout the fall.
3. **D**
When the ball is in contact with the ground and momentarily stationary, the normal contact force N must be greater than the weight W to provide the upward acceleration necessary for the ball to bounce back up. Thus, N>W. Therefore, the correct answer is D.
4. **A**
The mass of an object is accountable for its inertia.
5. **B**
In the absence of air resistance, all objects fall at the same rate regardless of mass. However, ball B with mass 4M and diameter D will hit the ground first if we consider minimal air resistance due to its higher mass to surface area ratio, reducing the effect of air drag slightly more than the others.
6. **C**
For mass M to accelerate down the slope, the component of gravitational force $Mg\sin\theta$ must be greater than the tension T = mg in the string. Thus, $Mg\sin\theta > mg$, simplifying to $\sin\theta > \frac{m}{M}$.
7. **C**
Momentum is conserved:
$mv = 3mv_{after}$
$v_{after} = v/3$
Initial Kinetic energy = $\frac{1}{2} mv^2$
After the collision, Kinetic energy = $\frac{1}{2}(3m)(v/3)^2 = 1/6\ mv^2$
$\Delta KE = 1/3\ mv^2$
Fraction of KE lost = ΔKE/initial KE = $(1/3\ mv^2)/(\frac{1}{2} mv^2) = 2/3\ mv^2$
8. **C**
Initially: $m_1 = m$, $m_2 = 2m$, $u_1 = 2v$, $u_2 = -v$
after collision: $v_1 = -v$
using conservation of linear momentum:
$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
$2mv - 2mv = -mv + 2mv_2$
$v_2 = v/2$
Initial kinetic energy= $\frac{1}{2} m(2v)^2 + \frac{1}{2}(2m)v^2 = 3mv^2$
Final kinetic energy= $\frac{1}{2} mv^2 + \frac{1}{2}(2m)(v/2)^2 = 3/4\ mv^2$
loss in Kinetic Energy = Initial KE - Final KE = $9/4\ mv^2$



9. **A**
Power = Fv
Since the power is constant, the product of F and v should also be constant. When two quantities are inversely proportional, their product is a constant. Hence for constant Fv, the graph of F-v should be that of inverse proportion so that the area under graph of F-v (i.e., power) is a constant. This is only true for A.

10. C

Air resistance opposes motion. When the ball is rising, the weight and air resistance both act downwards on the ball. Hence resultant force = mg + F

ma = mg + F

a = g + F/m

When the ball is falling, the weight acts downwards on the ball while air resistance acts upwards. Hence resultant force = mg - F

ma = mg - F

a = g - F/m

11. B

Force on 2-kg-sphere = Force on 4-kg-sphere (newton's third law pair of forces)

Force = ma

Force on 2-kg-sphere= 2 x 8 = 16

Force on 4-kg-sphere = 4 x a

$16 = 4a \Rightarrow 4\ m/s^2 = a$

12. B

For first experiment:

$F = ma \Rightarrow a = -F/m$ (negative sign since the car is decelerating)

$V^2 - u^2 = 2as$

$0 - u^2 = 2 \times 100 \times (-F/m)$

$u = \sqrt{200}\ F/m$

For the second experiment:

$F = ma \Rightarrow a = -0.800F/m$

$V^2 - u^2 = 2as$

$0 - 200F/m = 2 \times s \times (-0.800F/m)$

s = 125 m

13. C

$F = \Delta p/\Delta t$

At the instant the ball makes contact with the table, its speed is still unchanged {so, the momentum is still unchanged} and the rate of change of momentum [i.e. force] is INITIALLY zero.

After that instant, the speed of the ball decreases gradually {speed is changing, so momentum changes. Thus, force F gradually increases} until it becomes zero {at this instant, the change in speed, and hence the change in momentum, is maximum. So, force F is maximum at this instant}.Then, the speed of the ball increases in the opposite direction {while still in contact with the table}. So, the resultant force (reaction) F from the table gradually decreases} until it (that is, the speed of the ball) reaches a maximum speed in that opposite direction {at this instant, the resultant reaction force F from the table becomes zero}.

The table does not exert any force on the ball at the instant they make contact or at the instant they separate. The force must gradually increase and then decrease between these points, so only C could be correct.

14. B

As the golf ball reaches the surfaces after being dropped, all its potential energy is converted to kinetic energy.

$\frac{1}{2} m v_1^2 = mgh_1$

Speed v_1 as the ball reached the surface = $\sqrt{(2gh_1)}$

Similarly, the kinetic energy of the ball just as it leaves the surface is converted to potential energy at height h_2.

$\frac{1}{2} m v_2^2 = mgh_2$

Speed v_2 just as the ball leaves the surface = $\sqrt{(2gh_2)}$

The direction of motion of the golf ball changes after hitting the hard surface, so the initial momentum should be added.

Total change in momentum = $m(v_2+v_1) = m\sqrt{(2gh_1)} + m\sqrt{(2gh_2)}$

15. C

As the object is released from rest, its weight causes a downward acceleration. Since the object is accelerating, its speed will increase with time. Since the effects of air resistance are appreciable, as the object falls, there is an upward resistive force due to air resistance on the object. Air resistance increases with speed. So, as the speed of the object increases (due to its resultant downward acceleration), the force of air resistance increases. Hence the resultant force on the object decreases until it becomes zero (graph X); at this point, terminal speed has been reached and the object no longer accelerates and just falls at a constant speed. Hence initially the speed of the object increases as it accelerates until it reaches terminal velocity and speed becomes constant. This corresponds to Z. As the object falls its speed is increasing which means its height from the ground will decrease quicker and quicker (gradient of graph will increase) until the terminal velocity is reached which is when the gradient of height-time graph will become a straight line with non-zero gradient. This corresponds to Y.

16. A

From the force-time graph given, the force on the accelerator increases sharply to a constant value (indicated by the horizontal line in the graph) at a point. This causes a constant acceleration since F = ma. Acceleration is the rate of change of velocity. Since the acceleration is constant, the increase in velocity in uniform with time. This is represented by a straight line graph, showing that the gradient of the speed-time graph (which gives the acceleration) is constant.

17. C

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

Since the block moves from rest, u = 0.

$v^2 = 2as$

So, $v^2 \propto a$

Since a constant force is applied, F = ma, giving a = F/m

So, acceleration $a \propto 1/m$

Replacing the relationship $a \propto 1/m$ into the equation involving velocity,

$v^2 \propto 1 / m$

$v \propto 1 / \sqrt{m}$

18. B

A uniform/constant (no change in acceleration with time) acceleration means the Resultant force is also constant since F = ma.

If resultant force is zero, acceleration would also be zero. Hence A is incorrect.