Self Attempt Questions

1. (a) The time of contact is prolonged while the change in momentum remains the same. Hence the average force applied on the ball by hand will be reduced. By Newton's 3rd law, the force on hand by ball will be reduced.

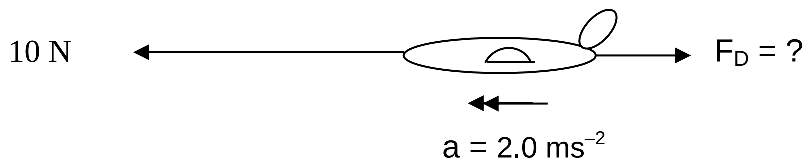
   (b) Prolonging the time of contact, it allows the force to be applied onto the ball for a longer time thereby increasing the change in momentum of the ball.

   (c) By Newton's 1st law, the object should fly forward when bus braked suddenly. The claim is not valid.

2. No. It only means that the net force is zero. For example, there can be two forces of equal magnitude acting on the object in opposite direction.

3. (a) Not possible. The acceleration must be in the same direction as the net force in accordance with Newton's Second Law.
   (b) Possible. Example: An object thrown vertically upwards.

4.



By Newton's 2nd law, Net force, F = ma

$$10 - F_D = 0.20 \times 2.0$$
$$F_D = 10 - 0.40$$
$$= 9.6 \text{ N}$$

5. Initial and final velocities of bullet u = 0 ms^{-1} and v = 320 ms^{-1} respectively.
   Since the force on bullet is assumed constant, the bullet undergoes constant acceleration a where a may be found from kinematics:

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

$$a = \frac{v^2 - u^2}{2s} = \frac{320^2 - 0^2}{2(0.82)} = 6.24 \times 10^4 \text{ ms}^{-2}$$

By N2L : force on bullet, F = ma

$$= 5.0\times10^{-3} \times 6.24 \times 10^4$$
$$= 312 \text{ N}$$

6.
$$
\begin{aligned}
F_{footballer\ exerts\ on\ ball} &= \frac{dP_{ball}}{dt} \\
&\approx \frac{P_f - P_i}{\Delta t} \\
&= \frac{m\left(v_f - v_i\right)}{\Delta t} \\
&= \frac{0.50(10-0)}{0.20}
\end{aligned}
$$
= 25 N acting in the direction of the initial motion of the ball.

7. (a) Impulse = change in momentum
= $m(v_f – v_i)$
= (70.0)(5.20 – 0) = 364 Ns

(b)
$$
\begin{aligned}
F_{on\ passenger} &= \frac{dP_{passenger}}{dt} \\
&\approx \frac{\Delta P}{\Delta t} \\
&= \frac{364}{0.832} = 438\ \mathrm{N}
\end{aligned}
$$

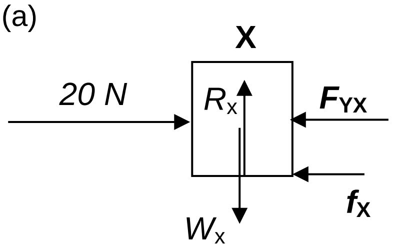
8. No. The initial total momentum of the system is not zero. For both objects to be at rest, the final total momentum of the system is zero. This would not be possible as it would violate the Principle of Conservation of Momentum. The assumption is there is no net unbalance external force.

9. Initially the clay has momentum directed towards the wall. When it collides and sticks to the wall, it appears that the momentum is zero. It is tempting to conclude that momentum is not conserved. In reality, the momentum of the clay is transferred to the wall and Earth, causing both to move although the speed is too small to be observable due to the enormous mass of wall and Earth.

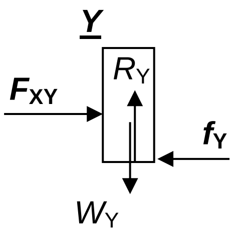
10 Linear momentum is not conserved. As the ball rolls down an incline, it experiences resultant force acting on it. The impulse will result in a change in momentum hence the momentum will increase. Linear momentum is only conserved when there is no external resultant force acting on the ball.

Tutorial Discussion Questions

11. (a)



F_{YX}: force by Y on X
W_X: weight by Earth on X
R_X: normal reaction force by floor on X
f_X: frictional force by floor on X



F_{XY}: force by X on Y
W_Y: weight by Earth on Y
R_Y: normal reaction force by floor on Y
f_Y: frictional force by floor on Y

(b) Consider forces on X:

$F_a - F_{YX} - f_X = m_X a_X$
$20 - F_{YX} - 6 = 3a$ *(Note: $a_X = a_Y = a$)*
$14 - F_{YX} = 3a$ ………..(1)

Consider forces on Y :

$F_{XY} - f_Y = m_Y a_Y$
$F_{XY} - 4 = 2a$ .... (2)

Consider forces on (X and Y) :

$F_a - f_X - f_Y = (m_X+m_Y)\ a$
$20 - 6 - 4 = 5a$
$10 = 5a$ …………..(3)

(c) From equation (3), $a = 2\ \text{ms}^{-2}$

(d) From equation (2), $F_{XY} - 4 = 2$
$F_{XY} = 8\ \text{N}$

By N3L, magnitude of force by Y on X, $F_{YX} = F_{XY}$,
magnitude of force by X on Y $F_{YX} = 8$ N

12. (a) When the acceleration is 2.0 ms^{-2}, what is the force exerted by the tow-bar on the trailer? [3000N]

Consider free-body diagram of trailer.

$$F_{net} = ma$$
$$T - f = ma$$
$$T = f + ma = 3000\ N$$

(b) When the tractor and the trailer are moving at a constant speed of 6.0 ms^{-1}, what is the force exerted on the tow-bar by the trailer?
[1000 N]

Moving at a constant speed of 6.0 ms^{-1} means no acceleration.

Force by tow-bar on trailer = Frictional force = 1000 N

By Newton's 3rd Law, force by trailer on tow-bar = force by tow-bar on trailer = 1000 N

13. Using the principle of conservation of momentum and taking vectors in the direction of the motion of the man to be positive:

initial momentum = final momentum

$$0 = m_{man}v_{man} + m_{book}(-v_{book})$$
$$= \left(\frac{730}{9.81}\right)v_{man} + 1.2(-5.0)$$
$$\therefore v_{man} = 0.0806\ \text{m s}^{-1}$$

Time taken for man to travel reach the shore $= \frac{5.0}{0.0806} = 62\ \text{s}$

14. (a) Initial weight of the rocket W = mg
= $(1.90 \times 10^3) \times 9.81 = 18639$ N

(b) By Newton's 2nd Law:

$$F_{rocket\ exerts\ on\ gas} = \frac{dP_{gas}}{dt}$$
$$\approx \frac{P_f - P_i}{\Delta t}$$
$$= \frac{m(v_f - v_i)}{\Delta t}$$
$$= \frac{7.40\ (2.50 \times 10^3)}{1}$$
= 18500 N downwards

By Newton's 3rd Law, the thrust (the force which the gas exerts on the rocket)
= 18500 N upwards

On ignition, the thrust acting upwards is less than the weight of the rocket. After some time, due to the ejection of gas from the rocket, the weight decreases such that the thrust is larger than the weight. The rocket is only then able to take-off.

Weight of fuel needed to be burn before take-off = 18639 – 18500 = 139 N
Mass of fuel needed to be burn before take-off = 139 / 9.81 = 14.2 kg
Time needed before take-off, t = 14.2 / 7.4000 = 1.9 s

15. (a) Impulse = area under F-t graph
= $\frac{1}{2}(3+5)(2) = 8$ Ns

(b) Impulse = change of momentum = $mv_f - mv_i$
Final velocity v_f = (impulse + mv_i)/m
= [8 + 1.5(0)]/1.5 = 5.3 ms^{-1}.

(c) Final velocity v_f = (impulse + mv_i)/m
= [8 + 1.5(-2.00)]/1.5 = 3.33 ms^{-1}.

16. $$\frac{dP_{ball}}{dt} = F_{net\ acting\ on\ the\ ball}$$
$$= W_{ball}$$
$$= 2 \times 9.81 = 19.6\ \mathrm{N}$$

17. In 1 hr, the mass of water hitting the roof

$$= volume \times density$$
$$= \left(A_{roof} \times 0.040\right)(1000) = 40A_{roof}\ kg$$

Taking upward vectors to be positive, the force which the roof exerts on the water

$$= \frac{\Delta P_{water}}{t}$$
$$= \frac{40A_{roof}[0-(-10)]}{60 \times 60} = 0.111A_{roof}\ \mathrm{N}\ (upwards)$$

By Newton's 3rd Law, force which the water exerts on the roof

$$= 0.111A_{roof}\ \mathrm{N}\ (downwards)$$

Hence pressure $= \frac{Force}{A_{roof}} = 0.111\ Pa$

18. (a) The principle of conservation of linear momentum states that the total momentum of a closed system of colliding objects remains constant if no unbalance external force act on the system.

(b) For elastic collision, both the total linear momentum and the total kinetic energy of the colliding objects are conserved.

For inelastic collision, the total linear momentum of the colliding objects is conserved but the total kinetic energy is not conserved.

(c) (i) Take vectors to the right as positive.
Let the velocity of the 5.00 kg mass be v_1 and that of the 10.0 kg mass to be v_2.

Using conservation of momentum,
initial total momentum = final total momentum

$$(5.00)(20.0) = 5.00\, v_1 + 10.0\, v_2 \quad \ldots . \quad (1)$$

Elastic collision means that total kinetic energy is conserved,

$$\frac{1}{2}(5.00)(20.0)^2 = \frac{1}{2}(5.00)v_1{}^2 + \frac{1}{2}(10.0)v_2{}^2 \quad \ldots . (2)$$

(Alternatively can use $v_{relative\ of\ approach} = v_{relative\ of\ separation}$)

Solving (1) and (2): $v_1 = -6.67\ \mathrm{ms^{-1}}$
$v_2 = 13.3\ \mathrm{ms^{-1}}$

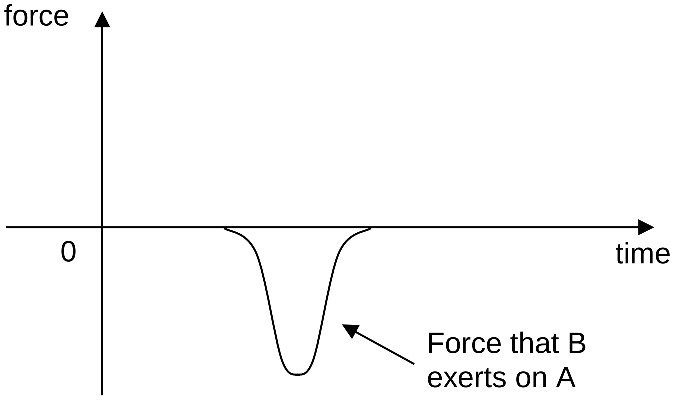
(ii) Fraction of initial KE transferred to the 10.0 kg object

$$= \frac{(KE_2)_f}{(KE_1)_i} = \frac{\frac{1}{2}(10.0)v_2^2}{\frac{1}{2}(5.00)u_1^2} = 2\left(\frac{13.3^2}{20.0^2}\right) = 0.884$$

19. (a) (i) The linear momentum of a body is the product of its mass and its velocity.

(ii) The change in linear momentum Δp of an object (impulse) is equal to the product of the constant force F acting on the object and the time Δt for which the force act. $\Delta p = F\Delta t$

(b) (i) The force that B exerts on A is shown in the figure below:



(ii) According to Newton's third law of motion, when body A exerts a force on body B, body B exerts an equal and opposite force on body A. Hence the force that B exerts on A is equal in magnitude but opposite in direction to that exterted by A on B.

(iii) The force that A exerts on B is equal in magnitude to that by B on A and the time of contact over which the forces act is also the same for both bodies.

The change in A's linear momentum ($\int F\, dt$) is thus equal in magnitude but opposite to B's ($-\int F\, dt$). Considering A and B as one system, their changes in linear momentum cancel out vectorially, thus the total momentum of the system remains unchanged.

Since their mutual contact forces are considered as internal forces and there are no external forces acting on the system, the fact that linear momentum of the system remains unchanged in the absence of external forces is consistent with the principle of conservation of momentum.

20. (a) (i) (Perfectly) Inelastic

(ii) Let the speed of the neutron before capture be u_1,

By principle of conservation of linear momentum,

$$m\,u_1 + m\,u_1 = 2m\,V$$
$$m\,u_1 + m\,(0) = 2m\,(3.0 \times 10^7)$$
$$u_1 = 6.0 \times 10^7 \text{ ms}^{-1}$$

(b) Let the speed of this 'heavy' nitrogen atom be V,

By principle of conservation of linear momentum,

$$m\,u_1 + 14m\,u_1 = 15m\,V$$
$$m\,(6.0 \times 10^7) + 14m\,(0) = 15m\,V$$
$$V = 4.0 \times 10^6 \text{ ms}^{-1}$$