Questions on Momentum MS

1. **Momentum**
   Use of \( p = m \nu \) (1)
   
   Total momentum = 0.32 kg m s\(^{-1}\) or N s (1)  
   
   **Velocity**
   Use of conservation of momentum (1)
   
   0.062 m s\(^{-1}\) [Allow e.c.f. from wrong first answer] (1)
   
   East/in same direction as B moved originally (1)
   
   [Only award last mark if momenta subtracted in first part]

2. 30 m ÷ (5 × 0.62 s)  
   = 9.7 m s\(^{-1}\) (2)
   
   \[(7000 \text{ kg} \times 9.7 \text{ m s}^{-1})\] [allow 10 m s\(^{-1}\) as e.c.f.]  
   = 68 000 (kg m s\(^{-1}\)) (2)
   
   Momentum before = momentum after  
   \[(7000 \text{ kg} \times 9.7 \text{ m s}^{-1}) + 0 = (7000 \text{ kg} + 5000 \text{ kg}) \times \nu\]  
   \[\nu = (7000 \text{ kg} \times 9.7 \text{ m s}^{-1}) ÷ (12 000 \text{ kg})\]  
   = 5.7 m s\(^{-1}\) [allow 5.8 if e.c.f. of 10 m s\(^{-1}\)] (3)
   
   Force = change in momentum ÷ time  
   \[= 7000 \text{ kg} \times [9.7 \text{ m s}^{-1} - 5.7 \text{ m s}^{-1}] ÷ 0.30 \text{ s}\]  
   = 93 000 N [98 000 N if 10 m s\(^{-1}\)used] (3)

3. **Experiment**
   
   2 light gates (1)
   Gate gives time trolley takes to pass [not just ‘the time’] (1)
   
   Speed = length of ‘interrupter’/time taken (1)
   
   OR
   
   2 ticker timers (1)
   Dots at known time intervals (1)
   
   Speed = length of tape section/time taken (1)  
   
   [ruler + clock could obtain third mark only, specifying a length/time]

   **Total momentum of trolleys**
   
   Zero (1)
   It was zero initially or momentum is conserved [consequent] (1)  
   
   **Speed \( \nu \) of A**
   Use of momentum = mass × velocity (1)
   Use of mass × speed (A) = mass × speed (B) (1)
   
   1.8 m s\(^{-1}\) [ignore -ve signs] (1)

4. **Momentum and its unit**
   
   Momentum = mass × velocity (1)
   
   kg m s\(^{-1}\) or N s (1)
   
   Momentum of thorium nucleus before the decay
Zero

Speed of alpha particle/radium nucleus and directions of travel

Alpha particle because its mass is smaller/lighter
So higher speed for the same (magnitude of) momentum
OR N3 argument
Opposite directions/along a line

5. Momentum of driver:
   Correct use of \( p = m \upsilon \) [OR with numbers] (1)
   \[ \begin{align*}
   &= 1500 \text{ N s OR } 1500 \text{ kg m s}^{-1} (1)
   \end{align*} \]

Average resultant force:
   Correct choice of \( F \times t = \Delta p \) OR \( F = ma \) (1)
   \[ \begin{align*}
   F \times 0.07 \text{ (s)} &= 1500 \text{ (N s)} \\
   &= 21 \text{ kN} \\
   \end{align*} \]
   [Ignore sign of answer]

   Why resultant force is not the same as force exerted on driver by seatbelt:
   Air bags /floor/friction/seat/steering wheel (1)
   [Named force other than weight/reaction] 1

6. Mass of head of mallet
   Selecting density x volume (1)
   Correct substitutions (1)
   Mass = 1.15 (kg) [3 significant figures, minimum] (1)
   Momentum change
   \( p = m \upsilon \) used (1)
   \[ \begin{align*}
   \Delta p &= 1.15 \text{ or } 1.2 \text{ kg (4.20 + 0.58) m s}^{-1} (1) \\
   &= 5.50 \text{ / } 5.74 \text{ kg m s}^{-1}/\text{N s} (1)
   \end{align*} \]
   Average force
   Their above \( / \) 0.012 s (1)
   \[ \begin{align*}
   F &= 458/478 \text{ N [e.c.f. } \Delta p \text{ above]} (1)
   \end{align*} \]
   Value for force
   Handle mass/weight/ head weight/force exerted by user (handle)
   neglected (1)
   Effectiveness of mallet with rubber head
   \( \Delta t \) goes up/\( \Delta p \) goes up (1)
   \( \Rightarrow \) less force, less effective/more force, more effective [consequent] (1)

7. (a) Newton’s Second Law of Motion
   (The) force (acting on a body) is proportional/equal to the rate of (1)
   change of momentum (1)
   and acts in the direction of the momentum change
   [accept symbols if all correctly defined for the first of these marks]
   [ignore any information that is given that is not contradictory] 2
(i) Calculate the mass
Correct calculation for volume of air reaching tree per second
[Do not penalise unit error or omission of unit] (1)
Correct value for mass of air to at least 3 sig fig [246 kg. No ue.] (1)
[If 1.23 × 10 × 20 = 246 kg is seen give both marks.
Any order for the numbers]
Example
20 ms\(^{-1}\) × 10m\(^2\) = 200 m\(^3\)
1.23 kg m\(^{-3}\) × 200 m\(^3\) = 246 kg

(ii) Calculate the momentum
Answer: [(246 kg × 20 m s\(^{-1}\) =) 4920 kg m s\(^{-1}\)]
[Accept (250 kg × 20 m s\(^{-1}\) =) 5000 kg m s\(^{-1}\). Accept 4900 kg m s\(^{-1}\). (1)] 2
Ecf value for mass. Ignore signs in front of values.]

(iii) Magnitude of the force
Answer: [\(F = 4920 \text{ N or } 5000 \text{ N or } 4900 \text{ N.}\]
[Ecf value from b(ii). Ignore signs in front of values] (1) 2

8. Definition of linear momentum:
Mass × velocity [Words or defined symbols; NOT ft] (1) 1
Newton’s second law:
Line 3 only (1) 1
Newton’s third law:
Line 2 OR 1 & 2 (1) 1
Assumption:
No (net) external forces/no friction/drag (1)
In line 3 (he assumes the force exerted by the other trolley is
the resultant force) [Only if 1\(^{st}\) mark earned] (1) 2
Description of how it could be checked experimentally that momentum is conserved in a
collision between two vehicles:
Suitable collision described and specific equipment to
measure velocities [e.g. light gates] (1) 1
Measure velocities before and after collision (1)
How velocities calculated [e.g. how light gates used] (1)
Measure masses / use known masses/equal masses (1)
Calculate initial and final moment a and compare OR
for equal trolleys in inelastic collision, then \(v_1 = \frac{1}{2} v_2\) (1) Max 4

9. Calculation of resultant force:
\[a = (v - u)/t = 16 \text{ m s}^{-1}[(4 \times 60) \text{ s}]\]
\[= 0.0666 \text{ m s}^{-2}\]
\[F = ma = 84000 \text{ kg} \times 0.0666 \text{ m s}^{-2} = 5600 \text{ N}\]
OR

Use of \( \frac{(v - u)}{t} \) \text{ use of } \frac{mv}{t} \hspace{1cm} (1)

Use of \( F = ma \) \text{ use of } \frac{mv}{t} \hspace{1cm} (1)

5600 N \hspace{1cm} 5600 N \hspace{1cm} (1) \hspace{1cm} 3

Free-body force diagram:

Diagram [truck can be just a blob] showing:

\[ \begin{align*}
840 \, 000 \, N \\
16 \, 800 \, N & \rightarrow 11 \, 200 \, N \\
840 \, 000 \, N \\
\end{align*} \]

\( 823 \, 200 - 840 \, 000 \, N \text{ down} \hspace{1cm} (1) \)
\( \text{same as down \uparrow} \hspace{1cm} (1) \)
\( 11 \, 200 \, N \text{ either way} \hspace{1cm} (1) \)
\( \text{correct resultant \rightarrow left} \hspace{1cm} \text{[e.c.f.]} \hspace{1cm} 4 \)

[Ignore friction. Each extra force \(-1\)]

Calculation of average power:

\[ \text{Power} = \text{KE gained/time} = \frac{1}{2}mv^2/t \hspace{1cm} \text{OR} \hspace{1cm} \text{KE} = 3.84 \times 10^8 \, J \hspace{1cm} (1) \]
\[ = 3.84 \times 10^8 \, J/(4 \times 60) \, s \hspace{1cm} (1) \]
\[ = 1.60 \times 10^6 \, W \hspace{1cm} \text{[OR J s}^{-1}] \hspace{1cm} (1) \]

\[ \text{Other credit-worthy responses:} \]

\[ \frac{1}{2} \, mv^2 \quad \text{Fv} \quad \frac{Fd}{t} \hspace{1cm} (1) \]

\[ \begin{align*}
\frac{3 \times 10^6 \times 16^2}{240} & \quad 3 \times 10^6 \times 0.666 \times 8 \\
\frac{3 \times 10^6 \times 0.666 \times 1920}{240} & \quad 1.6 \times 10^6 \, W \\
\end{align*} \]

\[ \text{[e.c.f. 0.666 and 1920 possible]} \hspace{1cm} 3 \]

Calculation of average current:

\[ P = IV = I \times 25 \, 000 \, V = 1.6 \times 10^6 \, W \hspace{1cm} \text{Use of } P = IV \hspace{1cm} 2 \]

\[ [12] \]