Multiple choice Solutions

Example 1 2010 Question 16, 59%

Momentum is always conserved.

$\therefore$ **B (ANS)**

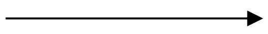
Example 2 2010 Question 17, 37%

Momentum is always conserved. This does not depend on whether the collision is elastic or in-elastic.

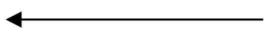
$\therefore$ **B (ANS)**

Example 3 2000 Question 3, 29%

This question is testing your understanding of vectors using momentum.
The cars initial momentum was to the right.

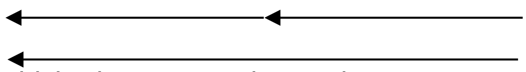


The cars final momentum was to the left.



The final momentum minus the initial momentum gives a change in momentum.
$\Delta p = p_f - p_i$. You are expected to do this with the vectors.
Thus:

This minus just changes the direction of the vector that follows it. Therefore you get:



Which gives you a change in momentum like this

$\therefore$ **D (ANS)**

Example 4 1994 Question 7

The driver of the truck slowed down, so the force acting on them was backward, this force was provided by the seatbelt. The driver of the car accelerated forwards, this acceleration was due to the force of the back of the seat on the driver.

$\therefore$ **D (ANS)**

Example 5 1982 Question 12, 71%

Momentum is conserved during the collision, but some of M_1's momentum is transferred to M_2.
The frictional force then causes the blocks to lose energy and momentum. The momentum from the blocks is transferred to the earth.

$\therefore$ **B (ANS)**

Example 6 1982 Question 13, 34%

The initial KE is $\frac{1}{2}M_1U^2 + 0$
The final KE is given by $\frac{1}{2}(M_1 + M_2)V^2$

The work done by the frictional force
$Fd = \frac{1}{2}(M_1 + M_2)V^2$
Some energy is lost in the collision, in deforming the putty etc.
$\therefore \frac{1}{2}M_1U^2 > Fd$
$\therefore$ **C (ANS)**

Example 7 1980 Question 30, 60%

Initially the two identical blocks are moving together at the same speed.
Therefore the initial momentum is zero, as they both have equal and opposite momentum.
Momentum is conserved in the collision, therefore the final momentum is zero.
$\therefore$ **D (ANS)**

Example 8 1978 Question 9, 60%

By definition the area under the F vs t graph is the Impulse (or change in momentum)
$\therefore$ **A C (ANS)**
Note that there were one or more answers.

Extended answer solutions

Example 9 2000 Question 1, 74%

$$x = ut + \frac{1}{2}at^2$$

$$\therefore 400 = 0 \times 16 + \frac{1}{2}a \times 16^2$$

$$\therefore a = \frac{2 \times 400}{16^2}$$

$= 3.12$ m s^{-2} (ANS)

Example 10 2000 Question 2, 74%

$$x = vt - \frac{1}{2}at^2$$

$$\therefore 400 = v \times 16 - \frac{1}{2} x\, 3.12 \times 16^2$$

$$v = \frac{800}{16}$$

$= 50$ m s^{-1} (ANS)

Example 11 1999 Question 1, 78%

Use $F\,\Delta t = m\,\Delta v$

$$\therefore F = \frac{7.0 \times 8.0}{1.6 \times 10^{-1}}$$

350 N (ANS)

Example 12 1999 Question 2, 53%

The airbag is designed to increase the time of the collision. It expands rapidly and is already deflating by the time the head comes into contact with it. This deflating bag increases the time of collision greatly. From the Impulse equation $F\Delta t = m\Delta v$ it can be seen that an increase in Δt for a fixed value of $m\Delta v$ will lead to a decrease in F.
Hard surfaces result in shorter contact times, or softer surfaces result in longer contact times
The larger F is, the greater the risk that parts of the body will undergo forces that will push the body beyond its elastic limit, resulting in injury.

Examiner's comment Question 2
The explanation required students to cover these main points.

- Impulse equals change in momentum.
  (**F**t = m**v** – m**u**)
- For this collision the change in momentum is a **fixed** quantity.
- Hard surfaces result in shorter contact times, or softer surfaces result in longer contact times.
- Hence, with the change in momentum fixed, then shorter contact times result in larger forces, or longer contact times result in smaller forces.

The above could also be addressed via a work-energy or force-acceleration approach as well.

Example 13 1985 Question 11, 93%

At time t = 3 s, the net force acting on the body = 6 N.
∴ Using F = ma
6 = 2.0 x a
∴ **a = 3.0 m s^{-2} (ANS)**

Example 14 1985 Question 12, 52%

The change in momentum is given by the area under the graph.
$\Delta p = \frac{1}{2} \times 10 \times 5$
= 25 N s (ANS)

Example 15 1985 Question 13, 27%

The work done is given by the change in KE. The initial KE is zero and final KE = ½ mv^2.
Use $F\Delta t = m\Delta v$ to find the final velocity.
∴ $25 = 2 \times \Delta v$
∴ $\Delta v = 12.5\ \text{ms}^{-1}$

$\Delta KE = \frac{1}{2}mv^2$
$= \frac{1}{2} \times 2.0 \times 12.5^2$
= 156.25
= 160 J (ANS) correct to 3 sig figs.

Example 16 1982 Question 11, 83%

Momentum is conserved in all collisions.
∴ $p_i = p_f$
∴ $M_1U + M_2(0) = (M_1 + M_2)V$
∴ $V = \dfrac{M_1U}{M_1 + M_2}$

Example 17 1982 Question 21, 36%

The ice skater will continue with the same velocity.
During this interaction there weren't any forces acting, so there wasn't any work done, so the KE remained constant.

∴ 5.0 m s^{-1} North (ANS)

From a momentum perspective, the parcel will continue to move at 5.0 m s^{-1} in a North direction.

Example 18 1980 Question 31, 24%

If ¾ of the KE is lost during the collision, then only ¼ of the initial KE remains.
Since KE is $\frac{1}{2}mv^2$, and the mass m is constant. This means that the final speed is ½ of the original.

∴ 2 (ANS)

Example 19 2001 Question 11, 23%

This question is worth 4 marks, so you should give at least four distinct answers. You must also answer the question in a clear manner. It is always useful to put your answer in point form. This question was meant to be a momentum question, but a lot of students used energy and forces to try to explain the answer. It was much simpler as a momentum question.

- If Jack pushes the box off the side of his toboggan, then it will have gained sideways momentum.
- As momentum is always conserved, then Jack also gains sideways momentum, but in the opposite direction.
- The box will still have its original downward momentum, so it will continue down next to Jack
- From a conservation of momentum, there will be no change in the forward momentum of the box or toboggan
- Lightening his toboggan will not cause Jack to gain or lose downhill momentum, so his speed will stay the same.
- If Jack really wanted to win the race, then he needed to project the box backwards
- Jill will remain in front and win the race.

Examiners comment Question 11

This question could have been answered using a conservation of momentum approach or by application of Newton's Second Law. Either way this will not be a successful way for Jack to win the race because it does not change the forward momentum of the box or toboggan.
This proved to be quite a difficult question with very few students scoring full marks (only about 7% of students scored the full 4 marks). It was anticipated that students would use conservation of momentum to address this question, but very few did. Most students attempted to answer using ***F = ma***. Many students **incorrectly** thought that mass affected the acceleration – stating either that less mass will allow the toboggan to go faster or conversely that greater mass will result in greater acceleration. Some even suggested that lighter objects accelerate at a greater rate.

Example 20 1998 Question 4, 70%

Momentum is conserved in all collisions.

∴ $p_f = p_i$.

Where p_i - sum of the initial momenta.

∴ $p_i = (4000 \times 15) + (1000 \times 0) = 60\ 000$ Ns.

∴ $p_f = 60\ 000 = (4000 \times 10) + (1000 \times v)$

∴ $60\ 000 = 40\ 000 + 1\ 000v$

∴ $20\ 000 = 1\ 000v$

∴ v = 20 m s^{-1} (ANS)

Example 21 1997 Question 9, 50%

The purpose of crumple zones is to extend the collision time and therefore reduce the average contact force during the collision.
Use $F\Delta t = m\Delta v$
If the change in momentum of the car is fixed at a value, because the car comes to rest from its initial speed, therefore increasing Δt will decrease F. This will minimise the injury to the occupants.

The crumple zone means that the car will be greatly deformed on collision, but the extra deformation of the car, means that the forces being applied to the car are less. This comes from the relationship that WD = ΔKE = F × d. With the car coming to rest from its initial speed then the change in KE is fixed. This means that with the 'd' being increased the resultant force is decreased.

Example 22 1994 Question 6

Momentum is conserved, so $p_i = p_f$
$\therefore p_i = 3000 \times 9.0 + m \times 0$
$= 27\,000$ (to the right, by my definition).

$\therefore p_f = 27\,000$ (to the right)
$= (3000 + m) \times 6$
$\therefore 27\,000 = 3000 \times 6 + 6m$
$\therefore 27\,000 = 18\,000 + 6m$
$\therefore 6m = 9000$
∴ m = 1500 kg (ANS)

Example 23 1994 Question 8

Use the impulse equation to solve this.
$\therefore F\Delta t = m\Delta v$
$\therefore 8000 \times \Delta t = 72.0 \times 6$
$\therefore \Delta t = 0.054$ sec
∴ 54 ms (ANS)

Example 24 1994 Question 9

Use the impulse equation to solve this.
$\therefore F\Delta t = m\Delta v$
$\therefore F \times 0.054 = 72.0 \times 3$
$\therefore F = 4\,000$
∴ 4 000 N (ANS)

Example 25 1994 Question 10

The crumple zone is designed to increase the time of the collision. This increase in the time of collision reduces the forces acting significantly.
From the Impulse equation $F\Delta t = m\Delta v$ it can be seen that an increase in Δt for a fixed value of $m\Delta v$ will lead to a decrease in F.
Stiff materials result in shorter contact times, the crumple zone results in longer contact times.
Injuries to the driver are caused by contact forces, i.e seatbelt, steering wheel, doors, and other panels. The larger these forces are, the greater the risk that parts of the body will undergo forces that will push the body beyond its elastic limit, resulting in injury.

Example 26 2008 Question 8, 85%

Momentum is conserved in this collision

$\therefore$ $p_i = p_f$

$\therefore$ $20 \times 10^3 \times 8 = 80 \times 10^3 \times v$

$\therefore$ **$v = 2$ m s^{-1} (ANS)**

Example 27 2008 Question 9, 63%

The impulse given to the locomotive by the trucks is equal and opposite to the impulse given to the trucks by the locomotive.
Impulse on trucks is change in momentum of trucks

$= m\Delta v$

$= 160 \times 10^3 \times 2$

$= 1.2 \times 10^5$ kg m s^{-1} West (ANS)

Example 28 2008 Question 10, 73%

If the collision is elastic, then $KE_{final} = KE_{initial}$.

$KE_{initial} = \frac{1}{2} mv^2$

$= \frac{1}{2} \times 20 \times 10^3 \times 8^2$

$= 64 \times 10^4$

$= 6.4 \times 10^5$

$KE_{final} = \frac{1}{2} mv^2$

$= \frac{1}{2} \times 80 \times 10^3 \times 2^2$

$= 1.6 \times 10^5$

$KE_{final} < KE_{initial}$

$\therefore$ KE is .lost

$\therefore$ **Collision is inelastic (ANS)**

Example 29 2008 Question 11, 55%

The magnitude of the impulse on both the locomotive and the trucks is the same.

Since $I = F \Delta t$

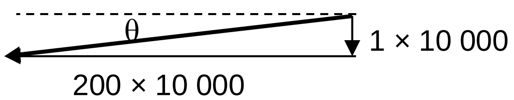
and the time of the collision is the same for both.

$\therefore$ **$F_L = F_T$ (ANS)**

(This is an example of Newton's Third Law, where $F_{A\ on\ B} = -F_{B\ on\ A}$)

Example 30 1969 Question 10, 61%

The initial momentum of the system
1 × 10 000 (downwards) + 200 × 10 000 (horizontal).
Use conservation of momentum.
So the final momentum will be the sum of the initial momenta.



$\therefore \tan\theta = \dfrac{1 \times 10000}{200 \times 10000}$

$\therefore \tan\theta = \dfrac{1}{200}$

$\therefore$ **$\tan\theta = 5 \times 10^{-3}$ (ANS)**

Example 31 1969 Question 28, 55%

The distance travelled is given by the area under the velocity time graph.

$\therefore$ d = 1 × (0.5 – 0.1) + $\frac{1}{2}$ × (1 + 2) × (0.9 – 0.5) + $\frac{1}{2}$ × (2 + 6) × (1.3 – 0.9)

$\therefore$ d = 0.4 + 0.6 + 1.6

$\therefore$ **2.6 m (ANS)**

Example 32 1969 Question 29, 56%

When the seven bricks were on the sled and the friction was zero, i.e. section B, the acceleration was

$\frac{2-1}{0.9-0.5}$ = 2.5 m s^{-2}

The total mass of the led and bricks was

8 × 2 = 16 kg

$\therefore$ force = 16 × 2.5

$\therefore$ F = 40 N

When the sled was on the carpet the acceleration was zero, therefore the frictional dforce was the same as the driving force

$\therefore$ **40 N (ANS)**

Example 33 1969 Question 30, 69%

Use F Δt = m × Δv

$\therefore$ I = 16 × 1

$\therefore$ **16 kg m s^{-1} (ANS)**

Example 34 1969 Question 31, 48%

The work done is given by the change in energy

$\therefore$ WD = $\frac{1}{2}$ × 16 × 2^2 - $\frac{1}{2}$ × 16 × 1^2

$\therefore$ WD = 32 - 8

$\therefore$ **24 J (ANS)**

Example 35 1969 Question 32, 53%

Since the force acting was constant, the impulse over any 0.4 s interval is the same.

$\therefore$ I = m × Δv (From Q 30)

$\therefore$ 16 = m × 4

$\therefore$ m = 4 kg

$\therefore$ the sled must have only one brick left on it.

$\therefore$ 6 bricks fell off.

$\therefore$ **6 (ANS)**

Example 36 1967 Question 15, 96%

There is a drop in velocity at 4 s due to a sudden increase in mass.

$\therefore$ **4 s (ANS)**

Example 37 1967 Question 16, 67%

From conservation of momentum

$\therefore$ 1 × 3 = m × 1

$\therefore$ m = 3

$\therefore$ the mass increased from 1 to 3 kg

$\therefore$**2 kg (ANS)**

Example 38 1967 Question 17, 93%

Use F = ma

$\therefore$ $F = 1 \times \frac{3-0}{2-0}$

$\therefore$ **1.5 N (ANS)**

Example 39 1967 Question 18, 90%

Use $KE = \frac{1}{2} m v^2$

$\therefore$ $KE = \frac{1}{2} \times 1 \times 3^2$

$\therefore$ **4.5 J (ANS)**

Example 40 1967 Question 19, 88%

Distance travelled is the area under the graph

$\therefore$ $d = \frac{1}{2} \times 2 \times 3 + 3 \times 2$

$\therefore$ **9 m (ANS)**