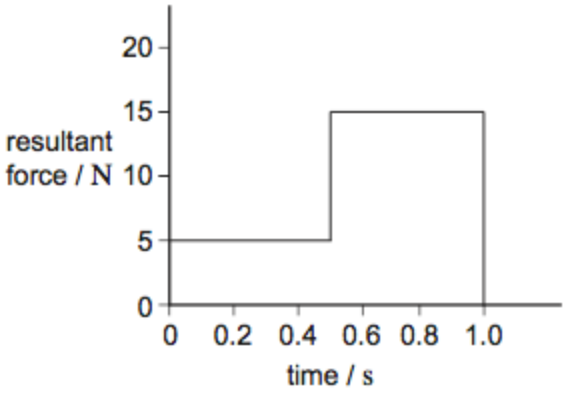
1 Which line, **A** to **D**, in the table correctly shows what is conserved in an elastic collision?

	Mass	Momentum	Kinetic energy	Total energy
A	conserved	not conserved	conserved	conserved
B	not conserved	conserved	conserved	not conserved
C	conserved	conserved	not conserved	conserved
D	conserved	conserved	conserved	conserved

(Total 1 mark)

2 The graph shows how the resultant force applied to an object of mass 2.0 kg, initially at rest, varies with time.



What is the speed of the object after 1.0 s?

A 2.5 m s^{-1}
B 5.0 m s^{-1}
C 7.5 m s^{-1}
D 10 m s^{-1}

(Total 1 mark)

3 Which one of the following has the same unit as the rate of change of momentum?

A work

B energy

C acceleration

D weight

(Total 1 mark)

4 The nucleus of a radioactive isotope X is at rest and decays by emitting an α particle so that a new nuclide Y is formed.
Which one of the following statements about the decay is correct?

A The momentum of Y is equal and opposite to the momentum of the α particle.

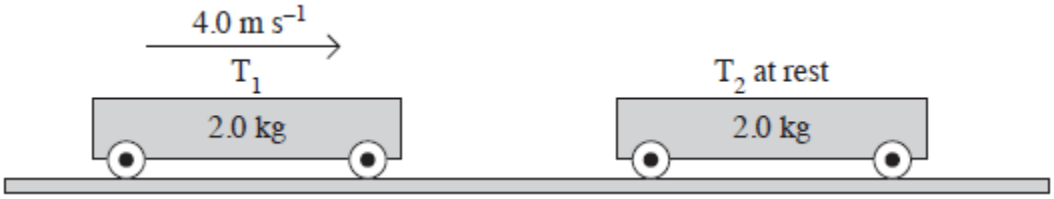
B The momentum of Y is equal to the momentum of X.

C The kinetic energy of Y is equal to the kinetic energy of the α particle.

D The total kinetic energy is the same before and after the decay.

(Total 1 mark)

5 Trolley T_1, of mass 2.0 kg, collides on a horizontal surface with trolley T_2, which is also of mass 2.0 kg. The collision is elastic. Before the collision T_1 was moving at 4.0 m s^{-1} and T_2 was at rest.



Which one of the following statements is correct?

Immediately after the collision

A T_1 is at rest and T_2 moves at 4.0 m s^{-1}.

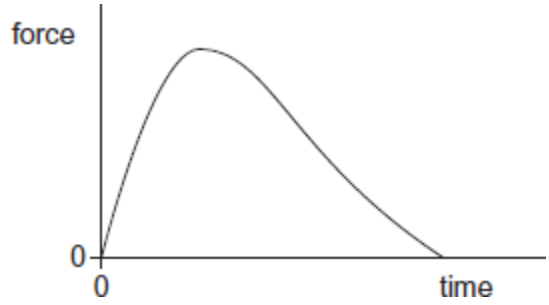
B T_1 will rebound from T_2 at 4.0 m s^{-1}.

C T_1 and T_2 will both move at 2.8 m s^{-1}.

D T_1 and T_2 will both move at 1.4 m s^{-1}.

(Total 1 mark)

6 The graph shows how the force acting on a rocket varies with time.



Which one of the following is represented by the area under the graph?

A distance travelled

B gain in kinetic energy

C change in velocity

D change in momentum

(Total 1 mark)

7 A golf club strikes a stationary golf ball of mass 4.8×10^{-2} kg and the ball leaves the club with a speed of 95 m s^{-1}. If the average force exerted on the ball is 7800 N, how long are the ball and club in contact?

A 5.8×10^{-4} s

B 1.2×10^{-2} s

C 0.51 s

D 0.58 s

(Total 1 mark)

8 Which one of the following is a possible unit of impulse?

A Ns^{-1}

B kg ms^{-1}

C kg ms^{-2}

D sN^{-1}

(Total 1 mark)

9 Water of density 1000 kg m^{-3} flows out of a garden hose of cross-sectional area 7.2×10^{-4} m^2 at a rate of 2.0×10^{-4} m^3 per second. How much momentum is carried by the water leaving the hose per second?

A 5.6×10^{-5} N s

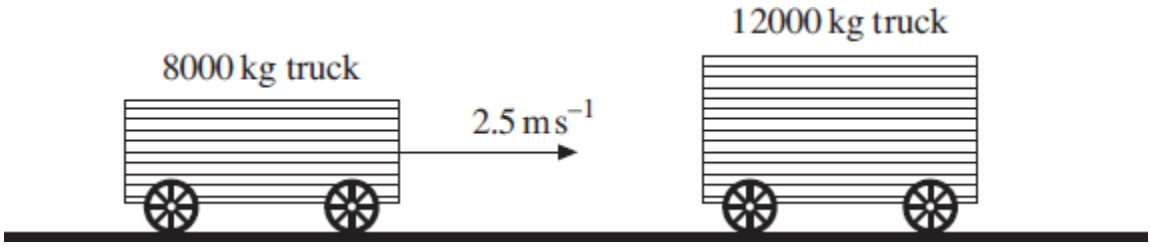
B 5.6×10^{-2} N s

C 0.20 N s

D 0.72 N s

(Total 1 mark)

10 A railway truck of mass 8000 kg travels along a level track at a velocity of 2.5 ms^{-1} and collides with a stationary truck of mass 12000 kg. The two trucks move together at the same velocity after the collision.



What is the change in momentum of the 8000 kg truck due to the impact?

A 8000 N s

B 12000 N s

C 20000 N s

D 25000 N s

(Total 1 mark)

11 A gas molecule of mass *m* moving at velocity *u* collides at right angles with the side of a container and rebounds elastically. Which one of the following statements concerning the motion of the molecule is **incorrect?**

A The magnitude of the change in momentum of the molecule is zero.

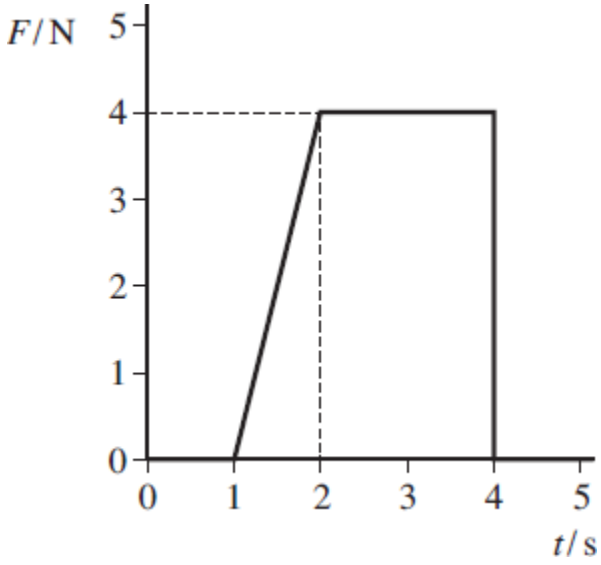
B The magnitude of the change in momentum of the molecule is 2*mu*.

C The force exerted by the molecule on the side of the container is equal to the force exerted by the container on the molecule.

D The change in kinetic energy of the molecule is zero.

(Total 1 mark)

12 The graph shows how the resultant force, *F*, acting on a body varies with time, *t*.



What is the change in momentum of the body over the 5 s period?

A 2N s

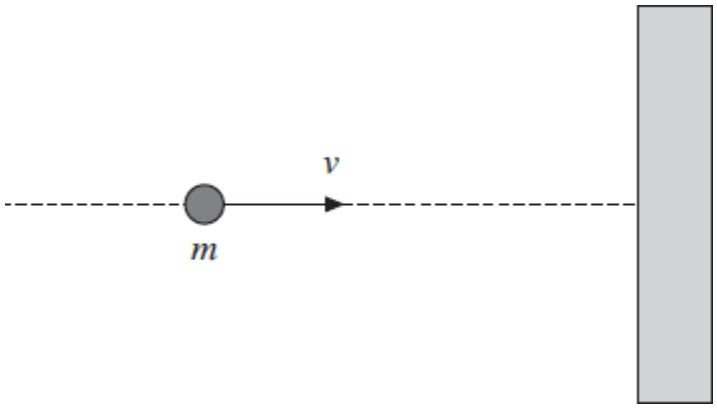
B 8N s

C 10N s

D 12N s

(Total 1 mark)

13 A ball of mass m travelling at velocity v collides normally with a smooth wall, as shown in the diagram, and rebounds elastically.



Which line, **A** to **D**, in the table, gives the correct expressions for the magnitude of the change of momentum, and the change of kinetic energy, of the ball?

	magnitude of change of momentum	**change of kinetic energy**
A	$2mv$	0
B	$2mv$	mv^2
C	0	0
D	0	mv^2

(Total 1 mark)

14 A cricket ball of mass 0.16 kg travelling at a speed of 35 ms^{-1} is hit by a bat and, as a result of the impact, leaves the bat in the opposite direction at 30 ms^{-1}. If the duration of the impact is 52 ms, what is the magnitude of the average force on the ball?

A 0.015 N

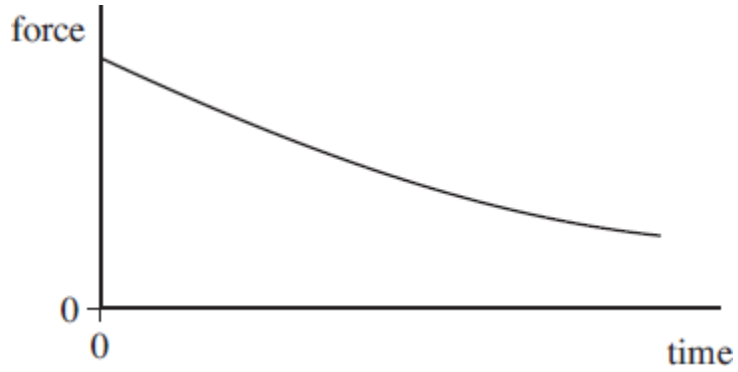
B 0.20 N

C 15 N

D 200 N

(Total 1 mark)

15 A ball is released so that it falls vertically. The graph shows how the resultant force acting on the ball changes with time.



Which one of the following is represented by the area under the graph?

A distance travelled

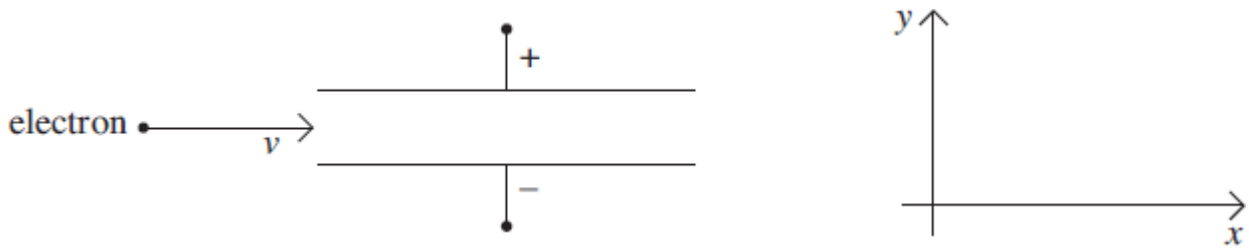
B gain in kinetic energy

C acceleration

D impulse

(Total 1 mark)

16 A beam of electrons, moving with a constant velocity v in a vacuum, enters a uniform electric field between two metal plates.



Which line, **A** to **D**, in the table describes the components of the acceleration of the electrons in the x and y directions as they move through the field?

	acceleration in x direction	**acceleration in y direction**
A	zero	zero
B	zero	constant
C	constant	zero
D	constant	constant

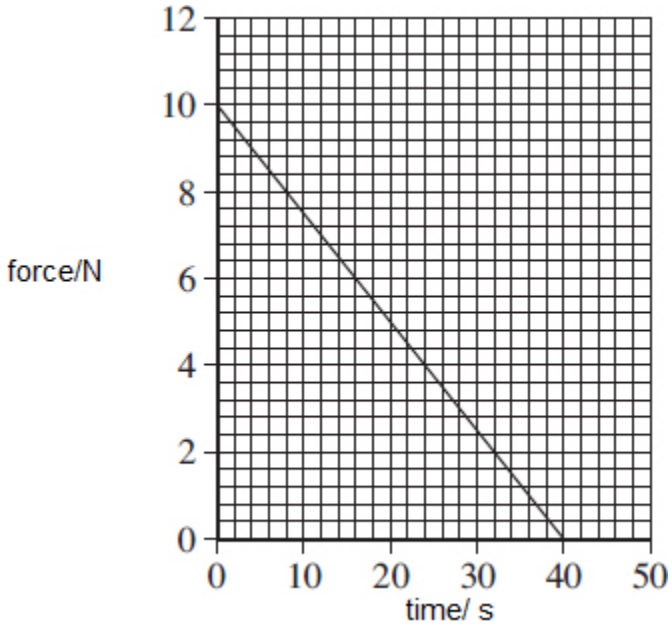
(Total 1 mark)

17 Which line, **A** to **D**, in the table correctly describes the trajectory of charged particles which enter separately, at right angles, a uniform electric field, and a uniform magnetic field?

	uniform electric field	**uniform magnetic field**
A	parabolic	circular
B	circular	parabolic
C	circular	circular
D	parabolic	parabolic

(Total 1 mark)

18 The graph shows how the force acting on a body changes with time.



The body has a mass of 0.25 kg and is initially at rest. What is the speed of the body after 40 s assuming no other forces are acting?

A 200 ms^{-1}

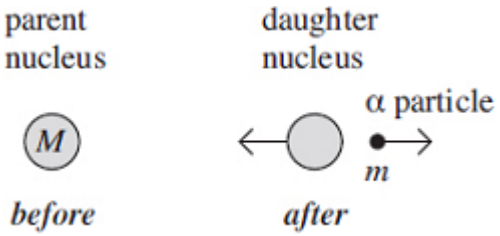
B 400 ms^{-1}

C 800 ms^{-1}

D 1600 ms^{-1}

(Total 1 mark)

19 A stationary unstable nucleus of mass *M* emits an α particle of mass *m* with kinetic energy *E*



What is the speed of recoil of the daughter nucleus?

A $\frac{\sqrt{2mE}}{(M-m)}$

B $\frac{\sqrt{2mE}}{M}$

C $\frac{(M-m)}{\sqrt{2mE}}$

D $\frac{2mE}{(M-m)^2}$

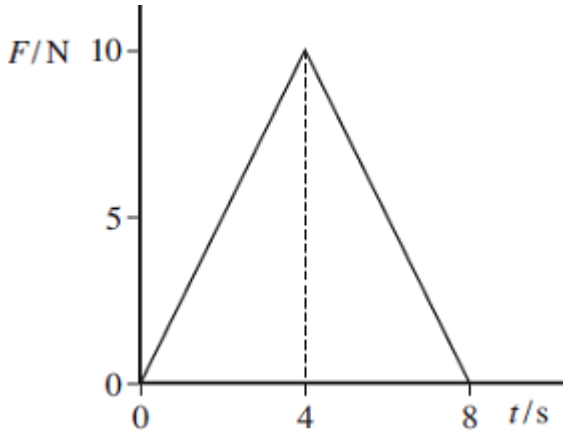
(Total 1 mark)

20 Two ice skaters, initially at rest and in contact, push apart from each other.
Which line, **A** to **D**, in the table states correctly the change in the total momentum and the total kinetic energy of the two skaters?

	total momentum	**total kinetic energy**
A	unchanged	increases
B	unchanged	unchanged
C	increases	increases
D	increases	unchanged

(Total 1 mark)

21 A ball of mass 2.0 kg, initially at rest, is acted on by a force F which varies with time t as shown by the graph.



What is the velocity of the ball after 8.0 s?

A 20 ms^{-1}

B 40 ms^{-1}

C 80 ms^{-1}

D 160 ms^{-1}

(Total 1 mark)

22 A body X moving with a velocity v makes an elastic collision with a stationary body Y of equal mass on a smooth horizontal surface.

Which line, **A** to **D**, in the table gives the velocities of the two bodies after the collision?

	velocity of X	velocity of Y
A	$\frac{v}{2}$	$-\frac{v}{2}$
B	$-\frac{v}{2}$	$\frac{v}{2}$
C	v	0
D	0	v

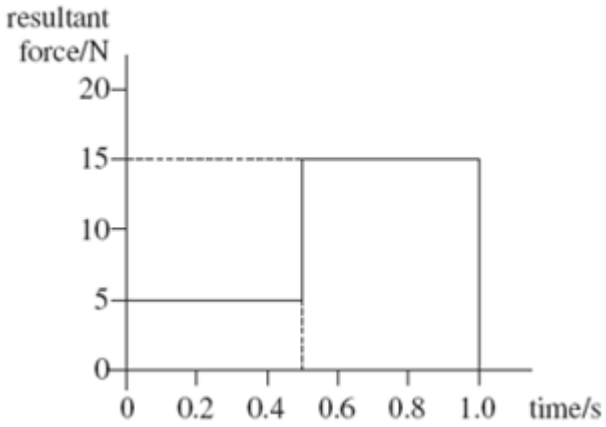
(Total 1 mark)

23 Which line, **A** to **D**, in the table shows correctly whether the moment of a force, and momentum, are scalar or vector quantities?

	moment of force	**momentum**
A	scalar	scalar
B	scalar	vector
C	vector	scalar
D	vector	vector

(Total 1 mark)

24 The graph shows how the resultant force applied to an object of mass 2.0 kg, initially at rest, varies with time.



What is the speed of the object after 1.0 s?

A 2.5 ms^{-1}

B 5.0 ms^{-1}

C 7.5 ms^{-1}

D 10 ms^{-1}

(Total 1 mark)

25 Which of the following is a possible unit for rate of change of momentum?

A N s

B N s^{-1}

C kg ms^{-1}

D kg ms^{-2}

(Total 1 mark)

26 A rail truck X travels along a level track and collides with a stationary truck Y. The two trucks move together at the same velocity after the collision.

Which line, **A** to **D**, in the table states how the total momentum and the total kinetic energy of the trucks change as a result of the impact.

	total momentum	**total kinetic energy**
A	unchanged	unchanged
B	unchanged	decreases
C	decreases	decreases
D	decreases	unchanged

(Total 1 mark)

27 What is the acceleration of an electron at a point in an electric field where the field strength is 1.5×10^5 V m^{-1}?

A 1.2×10^6 m s^{-2}

B 1.4×10^{13} m s^{-2}

C 2.7×10^{15} m s^{-2}

D 2.6×10^{16} m s^{-2}

(Total 1 mark)

28 Which one of the following statements is correct?

The force acting on an object is equivalent to

A its change of momentum.

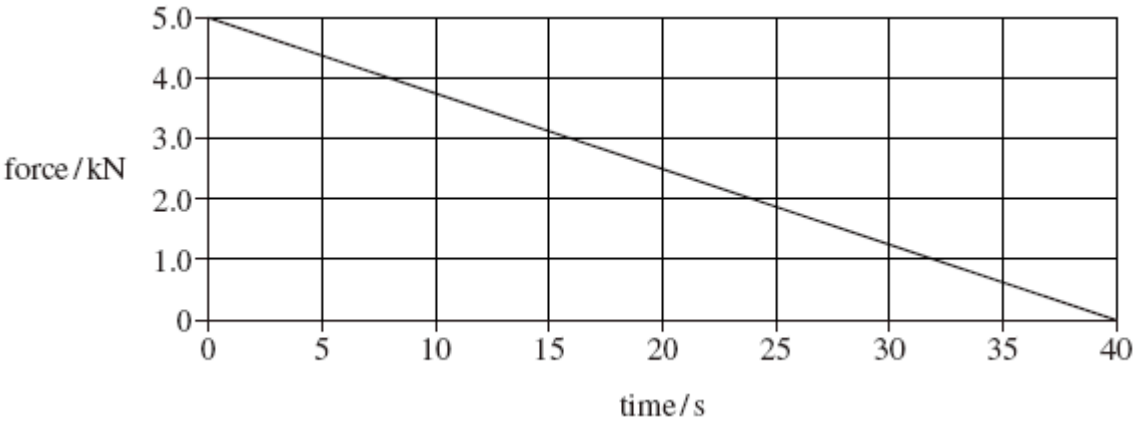
B the impulse it receives per second.

C the energy it gains per second.

D its acceleration per metre.

(Total 1 mark)

29 The graph shows how the force on a glider of mass 2000 kg changes with time as it is launched from a level track using a catapult.



Assuming the glider starts at rest what is its velocity after 40 s?

A 2.5 m s^{-1}

B 10 m s^{-1}

C 50 m s^{-1}

D 100 m s^{-1}

(Total 1 mark)

30 A gas molecule of mass *m* in a container moves with velocity *v*. If it makes an elastic collision at right angles to the walls of the container, what is the change in momentum of the molecule?

A zero

B $\frac{1}{2}mv$

C mv

D $2mv$

(Total 1 mark)

31 Which one of the following could **not** be used as a unit of force?

A A T m

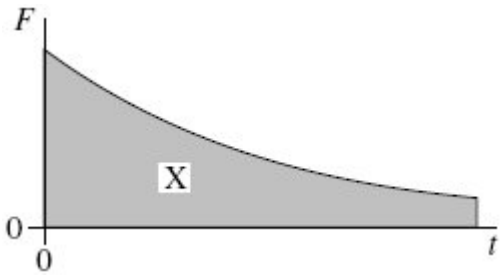
B W s^{-2}

C kg m s^{-2}

D J m^{-1}

(Total 1 mark)

32 The graph shows the variation with time, *t*, of the force, *F*, acting on a body.



What physical quantity does the area X represent?

A the displacement of the body

B the acceleration of the body

C the change in momentum of the body

D the change in kinetic energy of the body

(Total 1 mark)

Mark schemes

1	**D**	**[1]**
2	**B**	**[1]**
3	D	**[1]**
4	A	**[1]**
5	A	**[1]**
6	D	**[1]**
7	A	**[1]**
8	B	**[1]**
9	B	**[1]**
10	B	**[1]**
11	A	**[1]**
12	C	**[1]**
13	A	**[1]**
14	D	**[1]**
15	D	**[1]**
16	B	**[1]**
17	A	**[1]**

18	C	**[1]**
19	A	**[1]**
20	A	**[1]**
21	A	**[1]**
22	D	**[1]**
23	D	**[1]**
24	B	**[1]**
25	D	**[1]**
26	B	**[1]**
27	D	**[1]**
28	B	**[1]**
29	C	**[1]**
30	D	**[1]**
31	B	**[1]**
32	C	**[1]**

Examiner reports

1 This question, about the physical quantities that are conserved in an elastic collision, was answered correctly by 86% of the students. A question that turns out as easy as this becomes ineffective as a discriminator between the most successful and least successful students, and this question was the poorest discriminator in this test. 7% of the students thought that kinetic energy would *not* be conserved (distractor C).

2 This question had been used in a previous examination, when the facility was 51%; this time the facility improved to 80%. The most common incorrect response was distractor C, 7.5 m s^{-1}, which would have been correct if the resultant force had been 15 N throughout instead of 5 N for half of the time and 15 N for the remainder.

3 This question was more demanding than could have been expected, because it was answered correctly by only 60% of the students. Those who realised that “rate if change of momentum” is equivalent to force should have had no difficulty in seeing that weight is also a force and would therefore have the same unit. 20% of the responses were for distractor A (work).

4 This question was a representation of the explosion of a stationary object in the context of α particle emission. It should therefore be inconceivable that the kinetic energy would be the same before and after the decay, yet 19% of the responses were for distractor D. 69% of the students appreciated that the total vector momentum would be zero after emission, meaning that statement A was correct.

5 Collisions between dynamics trolleys of similar mass, the basis of this question, are often studied when considering the conservation of momentum. This was an elastic collision, and so kinetic energy would be conserved as well as momentum. Four out of five students decided that the moving trolley would stop and pass all of its momentum on to the other trolley.

6 This question was answered correctly by almost 95% of the students, who clearly recognised that the area under the graph was “force × time = impulse = change in momentum”. The surprising feature of this question is that when in was pre-tested in 2008 fewer than 60% of the students gave the correct response.

7 This question was a numerical test of “force × time = change in momentum”. This topic was not examined in Section B. Outwardly this question is more demanding than the previous one, but an even higher percentage of the answers were correct. Consequently this was the easiest question in the test. The ability of a question to distinguish the ablest students usually suffers when the facility is high (97% in this case); hence this was also the least discriminating question in the test.

8 This question tested familiarity with the units of impulse. The relationship between impulse and change of momentum pointed directly to kg m s^{-1}, which was chosen by two-thirds of the candidates. The common incorrect answers were distractors A (N s^{-1}: obviously confused with N s) and C (kg m s^{-2}, a unit of force rather than force × time).

9 This question, involving the momentum of a column of water emerging from a garden hose, had been used in a previous examination, when just over 40% of the students gave the correct answer. This time 61% did so, probably showing the benefit of practising on past papers. The most common incorrect response was distractor C, chosen by 19%, where the students had omitted to consider the cross-sectional area of the body of water leaving the pipe per second.

10 This question was a simple conservation of momentum calculation involving a collision between two trucks. 63% of the candidates selected the correct response by finding v to be 1.0 m s^{-1} from $8000 \times 2.5 + 0 = (8000 + 12000)\ v$, and then finding the change in momentum from $8000 \times (2.5 - 1.0)$.

22% of the candidates chose distractor C, which was the total momentum of the coalesced trucks, and 11% chose distractor A, which was the final momentum of the 8000 kg truck.

11 This question was the first of two questions in this test that required candidates to select an incorrect statement, a type of question which often challenges their logical reasoning. In the perfectly elastic collision at right angles between a molecule and the side of a container, the velocity of the molecule is exactly reversed. The change in momentum is therefore $mu - (-mu) = 2\ mu$. 70% of the candidates were aware of this, but almost a quarter of them thought the change in momentum would be zero (and therefore chose distractor A). Very few candidates chose the other two distractors.

12 This question required candidates to realise that change of momentum is equal to the impulse of a force, and that the answer is therefore represented by the area enclosed between the force-time graph and the time axis. 80% of them were able to do this correctly. Possibly it was inability to calculate the area of a triangle that caused 12% to choose distractor D.

13 This question tested the vector nature of momentum, the scalar nature of kinetic energy and the meaning of an elastic collision. Just over two thirds of the candidates realised that the exact reversal of momentum meant a change of $2mv$ and that an elastic collision meant no change in kinetic energy. Almost 20% of them chose distractor C, thinking there is no change in momentum.

14 More than one third of the candidates incorrectly chose distractor C in this Question, where an average force has to be calculated by applying $F = \Delta mv / \Delta t$. Just over half of them correctly chose alternative D. Undoubtedly the error of so many candidates was to fail to appreciate the vector nature of velocity and momentum. Distractor C would have been the correct answer had the change in velocity been 35 – 30 = 5 m s^{-1}.

15 This question concerned the significance of the area under a force-time graph. When this question was pre-tested just over half of the students gave the correct answer. The responses in the examination shows that candidates prepare much more seriously for real examinations than for pre-testing sessions, because it proved to be the easiest question in the paper.

16 This question required an understanding of whether the accelerations in two perpendicular directions are constant or zero when a beam of electrons travels through a uniform electric field. This was well known, giving over 70% of correct responses.

17 This question had appeared in an examination previously; it tested the fairly familiar knowledge of the trajectory of charged particles in electric and magnetic fields and this time had a facility of 71%.

18 This question was an easy starter that required the application of “change of momentum = area under force/time graph”. This question discriminated well, and just over two-thirds of the students gave the correct answer. The most popular incorrect response was distractor D, no doubt because the students who chose it overlooked the factor of ½ when calculating a triangular area.

19 Students often find that questions in which the result of a calculation is shown algebraically are harder than ones in which the calculation is purely numerical. In this question, where the recoil speed after an explosion was to be found in terms of kinetic energy. Just under half of the students arrived at the correct expression, and the question did not discriminate very well. 27% of the students selected distractor B, because they regarded the mass of the daughter nucleus still to be M (instead of $M - m$) after it had emitted the $\propto$ particle.

20 This question tested basic facts concerning the quantities that are conserved when two bodies – two skaters in this question – separate from each other with a release of kinetic energy. Almost 70% of the students gave the correct response. The most common incorrect response was distractor B, the students involved not realising that kinetic energy must increase when two stationary bodies start to move.

21 This question involved the calculation of an impulse from a force-time graph, and the consequent velocity of a body at rest that was then subjected to the impulse. The question discriminated well. Two-thirds of students arrived at the correct answer, whilst over a quarter of them selected distractor B, which was double the expected velocity. This may be because they forgot a factor of a half when calculating the area under a triangular graph.

22 An elastic collision between bodies of equal mass, one of which was stationary before the collision, was the subject of this question. Students who had witnessed such a collision on an air track, for example, should have had little difficulty in realising that the moving body stops whilst the second body moves off with all of the first body's momentum. Fewer than expected (56%) gave the correct response. It is difficult to see why 36% of the students selected distractor B, in which neither momentum nor kinetic energy would be conserved.

23 The principal hurdle in this question was to decide whether the moment of a force is a scalar or a vector. The vector nature of momentum was known by almost all. Nearly two-thirds of the candidates realised that a moment has an associated direction and gave the correct response. Over a quarter chose distractor B, where moment is a scalar and momentum a vector.

24 This was the most discriminating question in the test. Its facility was 51%. Distractor C accounted for 30% of the responses, probably because the candidates involved failed to notice that the force was 5 N (rather than 15 N) for the initial 0.5 s on the force-time graph.

25 It is surprising that only 49% of the candidates arrived at the correct answer in this question. Identifying the rate of change of momentum with force, and the unit of force with (mass × acceleration), ought to be relatively straightforward piece of physics for candidates at the end of an A level course. Distractors A and C (where in each case the answer is a unit of momentum) were both chosen by about 20% of the candidates.

26 This question was a test of momentum and energy conservation laws for colliding trucks. Almost all candidates realised that momentum would be conserved in this situation. Two-thirds of candidates knew that kinetic energy would not be conserved and one third thought that it would be conserved.

27 This question, requiring a combination of $F = EQ$ and $F = ma$, was the most discriminating question in the test; its facility was 67%.

28 This question was a test of the 'impulse = change of momentum' relationship. Almost two-thirds of the candidates selected the correct response. Nevertheless, 25% of candidates chose distractor A, showing a failure to understand the distinction between a change and a rate of change.

29 The surprising outcome of this question was that just as many candidates chose the wrong answer as the right one. This seems to have been caused by careless working. Forgetting that the mass of the glider was 2000 kg could have led candidates to the conclusion that its velocity would be 100 m s^{-1} (distractor D) instead of 50 m s^{-1}, or perhaps they forgot the factor of ½ when finding the area of the triangle under the graph line. The facility of this question was 40%.

30 This question tested the change of momentum of a gas molecule making an elastic collision with the walls of its container. Misunderstanding the vector nature of momentum, and therefore of the change of momentum, was responsible for the 21% of candidates who chose distractor A.

Their reasoning is likely to have been that $mv - mv = 0$, rather than the correct $mv - (-mv) = 2mv$, which 69% of the candidates selected.

31 This question contained a synoptic element, because two of the unit combinations quoted were mechanical. The facility of the question was 44%.

Overlooking the word not in the stem of the question presumably caused 34% of the candidates to choose distractor A, where $F = B\,I\,l$ ought to have shown that A T m is a correct unit of force.

32 This question, on factual knowledge of the impulse – momentum relationship, was an easy starter with a facility of 85%.