MARK SCHEME

PHYSICS

AS-Level

MOMENTUM

TEST 3

Mark schemes

1 (a) Max GPE of block = Mgh = 0.46 × 9.81 × 0.63 = 2.84 J ✓

The first mark is for working out the GPE of the block

1

Initial KE of block = $\frac{1}{2} Mv^2$ = 2.84 J

Initial speed of block v^2 = (2 × 2.84) / 0.46

v = 3.51 ms^{-1} ✓

The second mark is for working out the speed of the block initially

1

momentum lost by pellet = momentum gained by block

= Mv = 0.46 × 3.51 = 1.61 kg m s^{-1} ✓

The third mark is for working out the momentum of the block (and therefore pellet)

1

Speed of pellet = 1.58 / m = 1.58 / 8.8 × 10^{-3} = 180 ms^{-1} (183) ✓

The final mark is for the speed of the pellet

1

At each step the mark is for the method rather than the calculated answer

Allow one consequential error in the final answer

(b) As pellet rebounds, change in momentum of pellet greater and therefore the change in momentum of the block is greater ✓

Ignore any discussion of air resistance

1

Initial speed of block is greater ✓

1

(Mass stays the same)

Initial KE of block greater ✓

1

Therefore height reached by steel block is greater than with wooden block ✓

1

(c) Calculation of steel method will need to assume that collision is elastic so that change of momentum can be calculated ✓

1

This is unlikely due to deformation of bullet, production of sound etc. ✓

1

And therefore steel method unlikely to produce accurate results.

[10]

2 D

[1]

3 C

[1]

4 (a) (momentum of air) increases ✓

words implying increase

1

(b) (rate of change of momentum so) <u>force</u> acting <u>on</u> the <u>air</u> (Newton 2) ✓

1

<u>it/air</u> exerts <u>force</u> (on engine) of the <u>same/equal magnitude/size</u> ✓

1

but <u>opposite</u> in direction (Newton 3) ✓

allow backwards and forwards to indicate opposite

1

(c) *(use of $F = \Delta mv/t$)*

$F = 210 \times 570 = 120\,000$ (N) (119 700) ✓

1

(d) momentum/velocity is a vector OR momentum/velocity has direction ✓

1

there is a change (in the air's) <u>direction</u> ✓

1

(e) *(use of $F = ma$)*

$a = (-)\ 190\,000/7.0 \times 10^4 = 2.7$ (2.71) ($m\ s^{-2}$) ✓

1

(f) *(use of $v^2 = u^2 + 2as$)*

CE from 01.5

accept range 850 − 860

if forget to square u or double a score 1 mark

1

$0 = 68^2 - 2 \times 2.7 \times s$ ✓

$s = 68^2/(2 \times 2.7) = 860$ (m) (856)

accept alternatives using $s = ut + 1/2at^2$ OR average speed – first mark for time calculation AND correct substitution

1

(g) rate of intake of air decreases (as plane slows) OR volume/mass /amount of air (passing through engine) per second decreases ✓

allow argument in terms of (air) resistance

(air) resistance decreases as speed of aircraft decreases for 1 mark

1

(as) smaller rate of change of momentum OR momentum change ✓

NOT FRICTION

1

[12]

5 C

[1]

6 D

[1]

7 A

[1]

8 **D**

[1]

9 **B**

[1]

10 (a) $F\Delta t = \Delta p$ (or stated in words)
$\Delta p = 0.14 \times 0.4$ or 0.056

Accept use of F = ma with / in FΔt

Accept $4.67 \times 12 \times 10^{-3} = 0.056$

2

(b) $0.056 / 12 \times 10^{-3}$ or $0.06 / 12 \times 10^{-3}$
4.7 (4.67) (N)

Condone power of 10 error in t for C1 mark

Allow 1 sf answer of 5 (N) for 0.06 (kg m s^{-1})

2

[4]

11 D

[1]

12 (a) (i) use of $\left(s = \frac{1}{2}gt^2\right)$ OR $t^2 = 2s / g$ ✓

$t = \sqrt{\frac{2 \times 1.2}{9.81}}$ ✓

= 0.49 (0.4946 s) ✓ allow 0.5 do not allow 0.50

Some working required for full marks. Correct answer only gets 2

3

(ii) ($s = vt$)
= 8.5 × 0.4946 ✓ ecf ai
= 4.2 m ✓ (4.20) ecf from ai

2

(b) (i) $\left(s = \frac{1}{2}(u+v)\,t\right)$

$t = \frac{2s}{u(+v)}$ or correct sub into equation above ✓

$= \frac{2 \times 0.35}{8.5}$ = 8.2 × 10^{-2} (s) ✓ (0.0824) allow 0.08 but not 0.080 or 0.1

Allow alternative correct approaches

2

(ii) *a = (v − u) / t* OR correct substitution OR a = 103 ✓

(= −8.5) / 8.24 × 10^{-2} = 103.2)

(*F* = *ma* =) 75 × (103.2) ✓ ecf from bi for incorrect acceleration due to arithmetic error only, not a physics error (e.g. do not allow a = 8.5. Use of g gets zero for the question.

= 7700 N ✓ (7741) ecf (see above)

Or from loss of KE

Some working required for full marks. Correct answer only gets 2

3

[10]

13 A

[1]

14 D

[1]

15 B

[1]

16 B

[1]

17 C

[1]

18 (a) smooth curve with a maximum value shown

B1

condone non-zero at start and finish

gradient fairly constant or slight increase for half time

B1

falls gradually on second half of swing

B1

oscillations score zero

2 max

(b) impulse is product of force and time

B1

clear reference to impulse

prolonging the time (of contact) increases momentum / velocity

B1

being force time product needed for first mark

2

(c) (i) use of $F = mv/t$ $= 0.045 \times 58 / 180 \times 10^{-6}$

C1

use of 35 can gain first mark

or $a = 58 / 180 = 3.2 \times 10^5$ (ignore power for first mark) 1.45×10^4 (N)

A1

2

(ii) $(-)1.45 \times 10^4$ (N)

B1

numerically equal to c(i)

1

(iii) club head has inertia

C1

do not credit reference to friction

club head only slows slightly on impact

A1

club head still has kinetic energy / collision not elastic increase in internal energy / ‘heat’ / temperature of ball / club head

treat references to sound neutrally

2 max

[9]

19 B

[1]

Examiner reports

4 This question required students to apply their knowledge and understanding of mechanics to analyse the principles involved in the operation of a jet engine. Students for the most part were able to apply the appropriate physics ideas in their answers. In part (a) the vast majority of students appreciated that momentum increased. Part (b) in contrast, resulted in a much greater variation of response. Many students appreciated that Newton's third law was important here and were able to quote it correctly. However, they did not often produce complete answers, missing out important detail such as the engine exerts a force on the air or that the air exerts a force equal in magnitude on the engine. Weaker responses tended to try and involve air resistance in their explanations of why there was a forward force acting on the engine. The calculations required to answer questions (c), (e) and (f) were well done with full credit being commonly achieved. The only major mistake seen in part (f) was confusion between initial velocity and final velocity. Question (d) required an explanation of why the momentum had changed when the deflector plates were deployed. The majority of students did appreciate this was because the direction of the air's velocity had changed but did not then give a full answer by explaining that momentum and velocity are vector quantities. Question (g) was quite challenging and only the strongest responses were able to suggest that this might be due to the decrease in the mass of air entering the engine per second.

5 Over 68% of students were able to recall, or work out, the significance of the area under a force-displacement graph. Those who chose B (approximately 20%) were probably confusing force-displacement with force-time.

6 This proved to be a very demanding question with only 29% of students giving the correct answer, although it proved to be quite discriminating. Students were required to calculate the kinetic energy of the car, and divide this by the distance to find the average decelerating force. The same answer could be obtained by calculating the acceleration using the suvat equations, and using F = ma. Slightly more students gave the answer C than gave the correct answer, perhaps neglecting to square the speed when calculating the kinetic energy.

7 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.

8 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).

9 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.

10 Both parts were answered well.

11 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).

12 (a) (i) This was generally well done but a few used t = s / v. Some rounded 0.4946 to 0.495 and then rounded again to 0.50. This was penalised.

(ii) A large majority of candidates used a 'suvat' equation for this. Unusually, quite a few did so correctly with $a = 0$ and $u = v = 8.5$.

Many teachers encourage the 'suvat' equations to be applied for constant velocity situations and this is fine if the candidates know what to do. Nevertheless, the most common error was the use of 'suvat' with either $a = 9.81$ or $u = 0$.

For constant velocity situations, it is simply necessary to use, $s = vt$.
Those who did choose $v = s / t$, sometimes rearranged as $s = v / t$.

(b) (i) Uniform deceleration was implied in this question so a 'suvat' approach was appropriate with $s = 0.35$ m, $u = 8.5$ ms^{-1} and $v = 0$. Most errors were due to use of $t = s / v$ or using 9.81 for the acceleration.

A very large number of candidates rounded to 2 dp (0.08). This was forgiven here but it is not good practice. 2sf would be appropriate here (0.082). Many students clearly do not understand the difference between decimal places and significant figures.

(ii) Extensive use of $a = 9.81$ to calculate a horizontal force was seen. Very many candidates clearly did not fully understand the context. They identified a suitable equation but substituted the wrong values. There were many errors such as confusing distance with time, speed with acceleration. Not many used KE / displacement and most of those that tried tended to make errors. Quite a few candidates didn't attempt to answer this question.

13 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.

14 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.

15 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.

16 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.

17 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.

18 Most candidates were able to interpret the photograph sketching a sensible graph of club head speed against time. Many went on to describe how increasing the time of contact between the club head and the ball meant a greater change of momentum for the ball.

Although most candidates were able to attempt the calculation in (c)(i) there was frequent confusion regarding the choice of mass and velocity and also converting 180 μs into seconds. Approximately half the candidates recognised that the force acting on the club head and the ball were equal and opposite but it was rare for a minus sign to be included in answers to (c)(ii).

Answers to (c)(iii) were often too vague gain any marks – many simply saying that energy was lost as heat and/or sound but without explaining how the change occurred. Many recognised that the club head must retain kinetic energy to allow the follow through.

19 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.