MARK SCHEME

PHYSICS

AS-Level

MOMENTUM

TEST 1

Mark schemes

1 (a) (i) $1.5 \times 10^4 / 1.46 \times 10^4$ (14550) (kg m s^{-1})

B1

1

(ii) correct substitution into $t = (mv - mu)/F$
or (t =) $14550 \div 6.1 \times 10^3$ seen
(condone power of 10 error) [ecf from part ai]

C1

t = 2.39 s [ecf from part ai]

C1

correct substitution into $s = (u + v)t/2$
or (s =) $15 \times 2.39 \div 2$ seen
(condone incorrect value for a calculated t in substitution)

C1

s = 17.9 to 18 m [ecf from part ai]

A1

4

(b) (braking distance) increases/‘longer’ to stop

M0

greater mass

A1

more momentum/more time with rate of change of momentum equation

A1

same velocity change over longer time means greater distance /appropriate equation of motion with **s** as subject **and** longer time

A1

when using s = vt must identify v as average

or (braking distance) increases/‘longer’ to stop

M0

greater mass

A1

more ke (to convert)/more work to be done

A1

more work done by (same) force means greater distance/ appropriate equation with **s** as subject

A1

or (braking distance) increases/‘longer’ to stop

M0

greater mass

A1

smaller acceleration

A1

smaller acceleration for (same) change in velocity means greater distance/appropriate equation of motion with **s** as subject

A1

3

[8]

2 (a) force = rate of change of momentum **(1)**

1

(b) (i) area under graph represents impulse **or change in** momentum **(1)**

1

(ii) suitable method to estimate area under graph **(1)(1)**

[eg counting squares: 20 to 23 squares **(1)**
each of area $25 \times 10^{-3} \times 20 = 0.5$ (N s) **(1)**
or approximate triangle etc **(1)**
$\frac{1}{2} \times 250 \times 10^{-3} \times 90$ **(1)**]

gives impulse = 11 ± 1 **(1)**

N s (or kg m s^{-1}) **(1)**

4

(iii) use of impulse = $\Delta(mv)$ **(1)**

$\Delta p = mv - (-mu) = m(v + u)$ **or** $11 = 0.42\ (v + 10)$ **(1)**

giving $0.42\ v = 6.8$ and $v = 16$ (m s^{-1}) (impulse = 12 gives 19 m s^{-1}) **(1)**

answer to **2 sf** only **(1)**

4

(c) final speed would be lower **(1)**

any **two** of the following points **(1)(1)**

- initial momentum would be greater [**or** greater *u* must be reversed]
- change in momentum [or velocity] is the same [**or** larger *F* acts for shorter *t*]
- initial and final momenta are (usually) in opposite directions
- initial and final momenta may be in same direction if initial speed is sufficiently high

[alternatively]

final speed = $\frac{\text{impulse (from graph)}}{\text{mass of ball}}$ – initial speed **(1)**

gives final speed v = (26 ± 3) – initial speed u **(1)**

consequence is

- v is in opposite direction to u when $u < 26$
- v is in same direction as u when $u > 26$
- v is zero (ball stationary) when $u = 26$

any one of these bullet points **(1)**

3

[13]

3 D

[1]

4 (a) (i) clear working:

attempts to evaluate area under line
(12 – 13 squares × 0.1 N s)
or ½ × 106(105) × 24 × 10^{-3} seen

B1

1.260 – 1.272 (N s) 1.2 – 1.3 for square counting

B1

(ii) area under graph/impulse = Δmv

B1

22.3 (22.8) (m s^{-1})

B1

4

(b) use of Pythagoras $\sqrt{22.3^2 + 6.1^2}$ or $\tan^{-1}$ (6.1/22.3)

B1

or $\sqrt{20^2 + 6.1^2}$ or $\tan^{-1}$ (6.1/20)

22.8 – 23.8(m s^{-1}) 20.9 or 21(m s^{-1})

B1

14.9 – 15.5 (°) (15 – 16 (°)) 17/18(°)

B1

3

[7]

5

(a) use of E = mgh **(1)**

2680 J **(1)**

2

(b) use of $v^2 = 2$ as **(1)**

9.1 m s^{-1} **(1)**

2

(c) increases the time taken for the athlete to come to rest/reduced deceleration

force = mass × acceleration/mass × change in velocity/time **(1)**

or momentum argument

or energy argument **(1)**

2

[6]

6

(a) (i) (change in momentum of A) = – **(1)** 25 × 10^3 **(1)** kg m s^{-1} (or N s) **(1)**

(ii) (change in momentum of B) = 25 × 10^3 kg m s^{-1} **(1)**

4

(b)

	initial vel/m s^{-1}	final vel/m s^{-1}	initial k.e./J	final k.e./J
truck A	2.5	1.25	62500	15600
truck B	0.67	1.5	6730	33750
	(1)	**(1)**	**(1)**	**(1)**

4

(c) not elastic **(1)**
because kinetic energy not conserved **(1)**
kinetic energy is greater before the collision (or less after) **(1)**
[or justified by correct calculation]

3

[11]

7 (a) **total** momentum before a collision = **total** momentum after a collision or total momentum of a system is constant or $\Sigma mv = 0$, where mv is the momentum

B1

no external forces acting on the system/ isolated system

B1

2

(b) (i) work done = $F s$

C1

63 000 J

A1

2

(ii) KE = ½ mv^2 or $F = ma$ and $v^2 = u^2 + 2as$

C1

combined speed v = 4.6 (4.58) m s^{-1}

A1

2

(iii) reasonable attempt at a momentum conservation equation (2 terms before and one term after any signs)

C1

(+ or -) 3600 v + (2400 × 12.5) = (6000 × 4.58) (e.c.f)

C1

16 m s^{-1} (cao ignoring sign)

A1

3

(iv) driver A is likely to experience the greater force

B1

force = rate of change of momentum
($\Delta mv/t$) or $F = ma$

B1

time for deceleration on impact is (approximately) the same

B1

change in velocity of driver B = 11.4 m s^{-1} (ecf from (ii) and (iii))
and
change in velocity of driver A = 17.1 m s^{-1}
(ecf from (ii) and (iii))
or
Δmv or Δv of A > Δmv or Δv of B

B1

4

[13]

8 (a) (i) equation showing momentum before = momentum after **(1)**
correct use of sign **(1)**

(ii) no <u>external</u> forces (on any system of colliding bodies) **(1)**

3

(b) (i) (by conservation of momentum $m_1 v_1 + m_2 v_2 = 0$)

$0.25 \times 2.2 = (–)0.50 v_2$ **(1)**
$v_2 = (–)1.1(0) \text{ms}^{-1}$ **(1)**

(ii) = total k.e. = $\frac{1}{2} \times 0.25 \times 2.2^2 + \frac{1}{2} \times 0.5 \times 1.1^2$ **(1)**

= 0.91J **(1)**

4

(c) (i) mass of air per second = $\rho A v$ **(1)**
correct justification, incl ref to time **(1)**

(ii) momentum per second ($= Mv = v^2 A\rho$) $= v^2 A\rho$ **(1)**

(iii) force = rate of change of momentum (hence given result) **(1)**
upward force on helicopter equals (from Newton third law) downward force on air **(1)**

5

(d) $\upsilon^2 A\rho = \frac{mg}{2}$ (for 50% support) **(1)**

$\upsilon^2 \times 180 \times 1.3 = \frac{2500 \times 9.81}{2}$ **(1)**

gives υ = 7.2ms^{-1} **(1)** (or 7.3, g taken as 10)
if not 50% of weight, max 1 / 3 provided all correct otherwise (gives 10.2)

3

[15]

9 (a) (i) length of card
[or distance travelled by trolley A] **(1)**
time at which first light gate is obscured
[or time taken to travel the distance] **(1)**

(ii) time at which second light gate is obscured
[or distance travelled after collision and time taken] **(1)**

3

(b) momentum = mass × velocity **(1)**
mass of each trolley **(1)**
(check whether) $p_{\text{initial}} = p_{\text{final}}$ **(1)**

max 2

(c) incline the ramps **(1)**
until component of weight balances friction **(1)**
[or identify where the friction occurs **(1)**
sensible method of reducing **(1)**]

2

[7]

10 D

[1]

Examiner reports

1 Part (a) (i) was a very straight forward calculation and almost 80% of students managed it successfully.

Almost 50% of the students achieved all four marks in part (a) (ii). Of these, there were quite a few who altered signs and mixed up u and v in equations of motion. A good number of students correctly determined the time but then did not take into account that the fact that the velocity changed.

Most students were able to make some progress with part (b) but few were able to produce a response that fully answered the question. Many students were able to explain that a larger change in momentum occurred over a longer time but stopped short of why this produced a bigger braking distance. The explanations were often incomplete and lacked accuracy in their use of physics. Some students struggled with using appropriate technical language and confused terms such as power, momentum and force.

2 In this question candidates needed to appreciate the distinction between momentum and *change of momentu*m. In part (a), for example, the force is not the momentum per second but the change of momentum per second. Parts (a) and (b) (i) were answered well. In (b) (i) either 'impulse' or 'change of momentum' were accepted as a correct answer, 'momentum' was not accepted because it would only be true for a body initially at rest.

In part (b) (ii), a great variety of methods were used to estimate the area under the force-time graph, and most candidates seemed able to work towards an acceptable value. Common errors were incorrect scaling factors when changing the number of counted squares into an impulse, and overlooking the 10^{-3} in milliseconds.

Part (b) (iii) required care over signs when calculating the change of momentum; since the ball was stated in the question to return along its approach path it follows that u and v are in opposite directions and take opposite signs. This difficulty caused a high proportion of candidates to end up with an incorrect value for v, typically 36 m s^{-1} instead of 16 m s^{-1}. Examiners were expecting the final answer to be given to two significant figures, consistent with the data given in the question, but many candidates gave three.

Part (c), where candidates had to discuss the consequences of the same impulse on a higher approach speed, proved to be quite challenging. Some very good well-reasoned answers were seen. The principal conclusion, provided the ball still returns off the boot, had to be that its resulting speed would be lower. This is readily seen by realising that the initial momentum of the ball is greater but the change in momentum is the same. Credit was given for worthwhile principles in these answers, even if the wrong conclusion had been reached over the final speed. Examiners were pleased to see some rather profound answers which pointed out that, depending on how large the new approach speed, the ball could be stopped by the impulse or even continue in its original direction.

3 This was a straightforward test of candidates' knowledge. It required candidates to decide whether or not mass, momentum, kinetic energy and total energy would be conserved in an inelastic collision. 85% of the candidates appreciated that everything except kinetic energy would be conserved. Incorrect responses were fairly evenly spread around the other three distractors.

4 Only a minority of the candidates made progress with part (a) (i). The working in many responses did not convey a correct physics approach to the problem. Multiplying the peak force by half the time did not show that the aim was to determine the area, but rather that the aim was to find a number that fitted that given in the question. It would help demonstration of a correct approach to a problem, and in particular to 'show that' questions, if candidates were to include a subject for the formula and/or numerical substitution.

Candidates were generally more successful in part (a) (ii), almost half the candidates gaining both marks.

In part (b), candidates either coped very well or not at all with the straightforward task of finding the resultant magnitude and direction of the vector addition of horizontal and vertical velocities, both of which were given in the question. Many were unsuccessful because they could not successfully use Pythagoras' rule or identify the appropriate relationship to find the angle.

6 This was an unusual question and a considerable amount of work was required in parts (a) and (b). There were many opportunities to make errors. Part (a) was answered quite well but common errors were omitting the 10^3 factor, quoting both changes as positive and the usual unit problem that appears in questions involving momentum.

Part (b) caused real problems for a significant proportion of candidates and calculation errors were common. A significant proportion of candidates confused momentum with velocity and although they were then were able to score marks for a correct calculation of kinetic energy, arithmetic errors were common.

Part (c) provided evidence that there is a common misunderstanding of what is meant by an elastic collision. A relatively frequent response was that this was an example of an elastic collision because momentum was conserved.

7 (a) Most candidates were able to gain one mark for the definition. The most common errors were either not giving the condition of no external force or failing to refer to the total momentum in the definition. It was therefore unclear whether the definition referred to the momentum of a body or the system of bodies. There was a minority who stated the principle as 'the momentum of a body remains constant unless a force acts on it'.

(b) (i) This was usually correct.

(ii) A significant proportion of the candidates tried using the principle of conservation of momentum in this part. Those who appreciated that they had to use $KE = \frac{1}{2} mv^2$ usually completed this successfully but some used an incorrect mass or failed to take the square root.

(iii) There were many correct answers and many structured their responses sensibly. Most were able to make a realistic attempt equating two momenta before the collision to one momentum after. Many however failed to take account of the fact that the final momentum would be to the left whilst the original momentum of A is to the right and so the signs for these terms needed to be different, regardless of the convention they used.

(iv) There were some excellent logical arguments presented in response to this question and many gained full marks. Even weak candidates usually suggested that driver A would feel the greater force but explaining why proved more difficult. Some realised that use of $F = ma$ or $F = \Delta(mv)/t$ was useful but many went on to discuss the vehicles rather that the drivers. The most common omission was failure to state that in the comparison the time for each driver to come to rest would be (approximately) the same.

8 In part (a) most candidates were able to write down an equation relating the momentum before collision to the momentum after. However, many candidates failed to consider a sign convention even though the directions of velocity were clearly shown in the diagram. In part (a)(ii) many candidates did not state that no external forces act if momentum is to be conserved.

In part (b)(i) most candidates were able to calculate correctly the speed of trolley B after collision. Such candidates went on to calculate the kinetic energy after collision and quoted this as the minimum energy stored in the spring corresponding to an elastic collision.

Good candidates answered part (c) well and gained full, or near full, marks. However, this part proved to be too testing for weaker candidates, with many such candidates not attempting it. In part (c)(i) good candidates derived an expression for the volume of air flowing per second and multiplied this by the density of air to obtain an expression for the mass of air flowing per second. In part (c)(ii) the change in momentum per second is given by the mass per second multiplied by the velocity of the air. There were very few good answers to part (c)(iii). By equating the change in momentum with impulse an expression is obtained for the force exerted on the air. The force exerted on the helicopter is equal in magnitude but opposite in direction to that exerted on the air, a point missed by almost all candidates.

In part (d) it was common for candidates to forget to convert the mass of the helicopter to weight and to ignore the fact that only 50% of the weight of the helicopter is supported by the downward flow of air. The remaining 50% of the weight of the helicopter is supported due to the aerofoil section of the rotor blades.

9 This question was generally well answered throughout although it was clear that a significant number of candidates were unsure how light gates are used to determine velocity. Ideas for minimising friction were many and varied but very few candidates seemed aware of the concept of a friction compensated slope.