MARK SCHEME

PHYSICS

AS-Level

MOMENTUM

TEST 2

Mark schemes

1 (a) *(use of gain in E_k = loss in E_p)*

$1/2mv^2 = mgh$

$1/2v^2 = 9.81 \times 8.0$ ✓

$(v = \sqrt{(2 \times 9.81 \times 8.0)}) = 13\ (12.5)\ (\text{m s}^{-1})$ ✓

Bald correct answer scores 1 mark

If use $v^2 = u^2 + 2as$ then zero

Unless resolved g along slope

If use 10 for g (–1)

Gets second mark if answer rounds to 13

1
1

(b) THREE FROM:

acceleration of truck in Fig.1 is constant ✓

In Fig.2

acceleration is greater/greatest at start/top ✓

acceleration decreases ✓

reference to zero acceleration/uniform velocity between C and D ✓

because the component of weight/acceleration parallel to the slope changes ✓

1
1
1
(3 max)

(c) the loss of (gravitational) potential energy is the same

hence gain in kinetic energy is the same ✓

1

(d) THREE FROM:

rain has no (initial) <u>horizontal</u> momentum ✓

<u>vertical</u> momentum of rainwater decreases ✓

there is no external (horizontal) impulse/force on the truck (and water system) ✓

mass (of truck) increases but speed/velocity decreases ✓

<u>horizontal</u> momentum of water increases (but horizontal momentum of truck decreases by same amount) ✓

(so) no change in (horizontal) momentum of truck <u>and</u> collected water/total momentum ✓

If say: 'vertical momentum/velocity of rain drops/water changes to horizontal (momentum/velocity)' score 2 marks

Cannot score last mark if stated that speed/velocity of truck does not change

1
1
1
(3 max)

[9]

2 **D**

[1]

3 **A**

[1]

4 (a) (Total) <u>kinetic</u> energy ✓

1

(b) Attempt to apply conservation of momentum ✓

NB This is a 'show that' so all stages must be seen

1

$16\,000 \times 2.8 - 12\,000 \times 3.1 = 28\,000\, v$ ✓

Must see substitution

1

$v = 0.27(1)$ (m s^{-1}) ✓

Correct equation (watch signs) gets first and second marks

1

(c) Impulse = $16\,000(2.8 - 0.271)$ or $12\,000(3.1 + 0.271) = 4.0(5) \times 10^4$ ✓

If 0.3 m s–1 used then impulse will be 4.0×10^4 or $4.08(4.1) \times 10^4$

1

N s or kg m s^{-1} ✓

1

(d) Trucks move in opposite directions/rebound ✓

1

Velocity of **B** is greater than that of **A** because total momentum is to the right OR **B** has lower <u>mass</u> ✓

OR

Momentum of **B** after collision is same as that of **A** before the collision (and vice versa)

1

[8]

5 (a) $7.3(4) \times 10^5$ ✓

Numerical answer (in terms of powers of 10) must match unit prefixes where used

Penalise rounding errors (733944.9541)

C kg^{-1} ✓

Do not allow use of solidus in unit:

C / kg

Condone a capital k or lower case c but not a capital g

2

(b) (1300 (eV) =) 2.08×10^{-16}(J)

OR

2.1×10^{-16}(J) ✓

1

(c) Correct answer of 3.59×10^{7} gains 3 marks (without working)

(Number of Xe ions per second) =

$\frac{2.1 \times 10^{3}}{\text{ans to (b)}}$ OR $1(.01) \times 10^{19}$ seen ✓

Ecf from part (b)

(Mass of Xe ions per second)

$= 2(.2) \times 10^{-6}$ ✓

Ecf from part (b)

(time $= \frac{\textit{total mass}}{\textit{mass per second}} = \frac{79}{2(.2) \times 10^{-6}} =$) 3.59×10^{7}(s) or 3.6×10^{7}(s)

OR

(Total number of Xe ions) =

$\frac{79}{2.18 \times 10^{-25}}$ OR 3.6×10^{26} seen ✓

Ecf from part (b)

(total energy available)

$3.6 \times 10^{26} \times$ (ans to (b)) OR $7.5(4) \times 10^{10}$ ✓

Ecf from part (b)

(time $= \frac{E}{P} = \frac{7.5(4) \times 10^{10}}{2.1 \times 10^{3}} =$) 3.59×10^{7} (s) ✓

If both ‘methods’ attempted, restrict marks awarded to optimum method.

3

(d) Speed of He ions will be greater ✓

(Momentum depends on mass and speed, although) He (has higher speed) has (considerably) less mass, therefore less momentum (gained by He ion during the acceleration) ✓

He ion exerts less thrust (on spacecraft therefore xenon is better)

OR

Xenon ion exerts more thrust (on spacecraft therefore xenon is better) ✓

Must address these points

Other points (e.g. He smaller so more can be stored) are neutral: no credit awarded

Must be clear about which ion candidate is discussing

Condone use of terms such as 'heavier' / 'lighter'

3

[9]

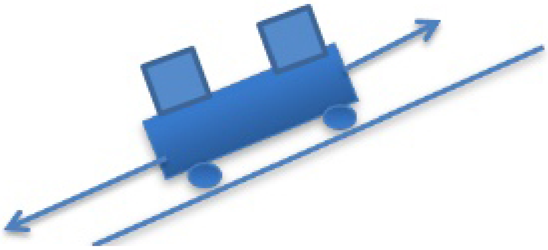
6 **B** **[1]**

7 **A** **[1]**

8 **D** **[1]**

9 **A** **[1]**

10 (a) arrow parallel to slope labelled (M+2m)gsin35 and label parallel to slope labelled tension OR T ✓



Ignore arrows not parallel to ground e.g. weight

Ignore friction

W not acceptable for (M +2m)g

1

(b) T – Mgsin35 = Ma
AND (M+2m)gsin35 – T = (M+2m)a ✓

add two equations

(M + 2m)gsin35 – Mg sin35 = Ma + (M +2m)a ✓

HENCE
(a= mgsin35 / (M+m))

OR
(M +2m)gsin35 – Mgsin35 ✓ (= (2M+2m)a)

a = 2mgsin35 /(2M +2m) ✓

HENCE
(a= mgsin35 / (M+m))

1
1

(c) SECOND MARK CONDITIONAL ON FIRST
mass / impulse / acceleration (of trollies) is the same ✓
momenta (trolley A and B) the same

SECOND MARK CONDITIONAL ON FIRST

both have same <u>speed / magnitude of velocity</u> but different masses ✓

(hence) momentum of A is greater / momenta in opposite directions ✓

1
1

(d) $\text{acceleration} = \frac{1}{4} \times \frac{30 \times 9.81 \times \sin 35°}{(30 + 95)} = 0.338$ ✓

(use of $v^2 = 2as$)

$v = \sqrt{(2 \times 0.338 \times 9.0)} = 2.47$ ✓

$t = \frac{2.47}{0.338} = 7.3\text{s}$ ✓

OR
(use of $s = 1/2at^2$)
$9 = ½ \times 0.338 \times t^2$ ✓
$t = 7.3$ s ✓

CE from acceleration calculation

If used g for acceleration then no marks awarded

1
1
1

(e) number of journeys = (1800/(12 + 7.3) = 93 or 94 ✓

number of blocks = 2 × 93 = 186 or 2 × 94 = 188 ✓

Allow CE from 06.4

Allow between 93 to 94

Allow CE from incorrect number of journeys

Allow 186 to 188

1
1

[10]

11 **B**

[1]

12 (a) Attempt to determine area under graph or statement that area under needed or 0.5 × 15 × 10^{-3} x 66 ✓

0.495 (N s)✓

condone power of 10 error

2

(b) Momentum before = 0.045 × 7.1 = 0.320 (N s) <u>down✓</u>

Momentum after = 0.045 × 3.9 = 0.175 (N s) <u>upwards✓</u>

<u>Change = 0.495 (N s) ✓</u>

3

(c) Initial KE on impact = 0.5 × 0.045 × 7.1^2 = 1.13 (J) or Ke after impact = 0.342 (J)✓

Fractional change ke after / ke before = 0.30✓

Use of their fractional change cubed✓

Percentage change after 3 bounces = 0.3^3 × 100 (%) = 2.7%✓

4

(d) As ball falls momentum of ball toward the Earth (always) = momentum of Earth toward the ball✓

On impact the momentum of both ball and Earth become zero✓

After impact momentum of ball away from Earth = momentum of Earth in opposite direction✓

3

[12]

13 C

[1]

14 B

[1]

15 (a) $m = 16$ g = 0.016 kg $r = 0.008$ m

Use of $V = 4 / 3\ \pi\ r^3$ to give $V = 4 / 3\ \pi\ (0.008)^3$

$= 2.1 \times 10 - 6\ m^3$✓

The first mark is for calculating the volume

1

Use of density = m / V to give density = $0.016 / 2.1 \times 10^{-6}$✓

The second mark is for substituting into the density equation using the correct units

1

Density = 7.4×10^3 kg m^{-3} ✓

The final mark is for the answer.

1

(b) Use of $v^2 = u^2 + 2as$ to give $v^2 = 2\ (9.81)\ (1.27)$ ✓

(allow use of $mg\Delta h = ½\ mv^2$)

$v^2 = 25$ (24.9)

The first mark is for using the equation

1

$v = 5.0$ (m s^{-1}) ✓

The second for the final answer

1

(c) Use of $v2 = u2 + 2as$ to give $0 = u^2 + 2\ (-9.81)\ (0.85)$ ✓

The first mark is for using the equation

1

$u^2 = 17$ (16.7)

$u = 4.1$ m s^{-1} ✓

The second for the final answer

1

(d) Change in momentum = $mv + mu = 0.016 \times 5 + 0.016 \times 4.1$✓

The first mark is for using the equation

1

= 0.15 (0.146) kg m s^{-1} ✓

The second for the final answer

1

(e) Use of Force = change in momentum / time taken

= $0.15 / 40 \times 10^{-3}$ ✓

The first mark is for using the equation

1

= 3.6 N ✓

The second for the final answer

1

(f) Impact time can be increased if the plinth material is not stiff ✓

Alternative

A softer plinth would decrease the change in momentum of the ball (or reduce the height of rebound) ✓

1

Increased impact time would reduce the force of the impact. ✓

Smaller change in momentum would reduce the force of impact ✓

1

[13]

Examiner reports

1 This question required an understanding of the vector nature of acceleration and momentum and also how using energy considerations can lead to a simpler analysis due to it being a scalar quantity.

(a) This was a straightforward calculation but a lot of students were caught out because they used $v^2 = u^2 + 2as$ instead of energy considerations. This meant that they did not get credit for their answer unless they allowed for the different directions of v, a and s.

(b) Some good responses were seen to this question although it was not uncommon for contradictory statements to be made. Most students were able to state that acceleration was constant in figure 1 but analysis of figure 2 proved more of a challenge. It was quite common to see answers that referred to speed rather than acceleration decreasing as the truck moved down the ramp. Also, a significant proportion of students thought that the truck decelerated between C and D. A quarter of students managed to gain all three marks.

(c) Only more able students could give a satisfactory explanation for the speeds being the same (19.8% correct).

(d) This was a challenging question that required a good understanding of momentum conservation in closed systems and also the importance of direction in momentum considerations. Very few students managed to give complete discussions. The commonest answer was that as mass went up momentum increased, with students failing to appreciate that with no external horizontal forces acting, this could not be the case. Better students did appreciate that the total horizontal momentum remains constant and so as mass increases speed must decrease. It was very rare for there to be a discussion of how the momentum of the rain water changes from vertical to horizontal. Nearly three-quarters of students failed to score on this question.

2 This question was demanding, with only 18.8% of students able to select the correct answer. The most frequently selected incorrect answer was distractor A. The two approaches used were to realise the significance of the area under the force-time graph or alternatively to realise the significance of the gradient of the momentum-time graph.

3 Students found this question challenging; there was a success rate of just over 20%. The most common incorrect response seen was distractor C. Quite often this was selected without any evidence of supporting calculations.

4 (a) That kinetic energy would be conserved in an elastic collision was well known (64.5% correct).

(b) Most students knew how to arrive at the answer (75.3% fully correct), but responses were often completely unstructured and consisted of a mass of figures and calculations with no indication of what the calculation represented. In questions where the command word is 'calculate' this may often be accepted, but in 'show that' items communication of the processing of data needs to be clear.

(c) The same impulse on each of the trucks is equal and opposite so students needed to focus on one or other of the trucks involved. There were many who misread the data and associated the initial velocities with the wrong trucks. Many gave the impulse as the difference between the final momenta of the two trucks.

(d) It was necessary here to have a qualitative appreciation of the application of conservation of momentum and kinetic energy in the elastic collision. It is not possible to conserve both unless the trucks travel in opposite directions after the collision, and many appreciated this point. Many students, however, went on to state that the speed of each truck would be the same as before but in the opposite direction; others wrote that B would have the speed that A had and vice versa. The first conserves kinetic energy but not momentum (total momentum would be reversed) and the second would only be true if they had the same mass. If A were to stop, as suggested by many students, then to conserve momentum B would need to travel at a lower speed than either of the trucks (since the initial total momentum was 7600 Ns to the right, B's speed would need to be 0.63 Ns). This would not conserve kinetic energy. 38.5% of students were successful here.

5

(a) A significant number of students had difficulty with this question. Common wrong answers included:

- Mass divided by charge
- The charge = 53 × 1.6 × 10^{-19} arriving at an answer = 3.9 × 10^{7}

Other students could not recall the units for specific charge; the coulomb and the joule were common wrong answers. Students who did not express the unit using index notation did not receive the mark.

(b) Many students could not convert 1300 eV into its equivalent 2.1 × 10^{-16} J.
A common error seen was 1300 ÷ 1.6 × 10^{-19} = 8.125 × 10^{21}

(c) A wide range in the quality of response seen here. Those who obtained 3 marks typically presented their working in a way that demonstrated a good understanding of the calculation required. Students who made some progress typically by determining the number of xenon ions in 79 kg obtained some credit. There was a significant number of non-attempts seen.

(d) Some students thought that the helium ion had more charge than the xenon ion because helium had a higher specific charge. On this basis, they stated that the helium ion had a greater speed. Getting the correct relationship between specific charge and mass was a sign of quality. Others thought that helium's greater specific charge meant it had a greater mass than xenon. Despite this error, students were still awarded the higher speed mark for helium. Other students confused specific charge with activation energy and gave answers in terms of combustion rates.
Students often confused the terms speed and acceleration. A common error was to state that the acceleration of the helium ion was greater, without linking this to a greater speed. Better students made reasoned arguments regarding the relationship between energy, speed and momentum. Frequently, they stopped short of linking this to the thrust exerted on the space craft. In these cases, the students would limit their answer to momentum change of the propellant rather than relating this to the effect on the spacecraft.

6

15.0% correct

7

45% of students selected the correct answer, with 33% of students incorrectly selecting distractor B. Students seemed unwilling to consider the total momentum as being zero despite this application of momentum conservation being clearly stated in the specification content.

8

Most students were able to determine the momentum gained by the object. Each of the distractors gained about 15% of student responses.

9 Almost 50% of students selected distractor B. Students were unable to see that the force was the same on both masses. Students often have difficulty in distinguishing between force and acceleration, as was the case here. The smaller mass will experience a greater acceleration but this is due to its inertia and not the size of the force it experiences. As momentum is conserved, then the momentum lost by one object is equal to the momentum gained by the other. The magnitude of the momentum change is the same for both objects. The forces acting between the objects can only act while they are in contact, therefore the time over which the momentum change occurs is the same for each.

Momentum change = impulse = force × time

$$\text{Same force} = \frac{\text{same momentum change}}{\text{same contact time}}$$

Alternatively, these forces are internal forces in a two-body system, constituting an example of Newton's third law, and must be equal in magnitude.

10 The responses to this question showed significant variation with students performing significantly better in the quantitative parts than they did in the qualitative.

The majority of students failed to identify the forces acting on the trolley that were parallel with the slope. It was rare to see the component of the combined weights of trolley and blocks identified. Also, the majority of diagrams included forces which were not required such as the reaction force.

Question (b) involved an algebraic derivation of the acceleration of the trolley – this proved quite a challenge for some and responses had to be scrutinised carefully to see if they were valid. Many provided a correct formula for the resultant force on trolley A but then incorrectly stated that the tension was equal to the component of trolley B's weight along the slope. The more successful answers treated the trollies as a system with a resultant force acting equal to (M + 2m) gsin35 – Mgsin35 and a combined mass of 2M + 2m.

There was a typographical error in question (c) which led candidates to assume that loaded trolley A was being compared with loaded trolley B. The question originally intended to ask students to compare loaded trolley A with unloaded trolley B (as shown in Figure 2). We judged that both interpretations should be allowed and revised the mark scheme to permit the two different approaches. Either approach could achieve 0, 1 or 2 marks according to the accuracy of the answer. Student responses to this question were carefully scrutinised to assess the impact of the typographical error, and there was no evidence that students were unable to generate meaningful responses to this question.

The conclusion mark of how the momenta compared was then conditional on the first mark being awarded. The multi-step calculations in (d) and (e) were well done, with a high proportion of students scoring at least 3 of the 5 marks available.