A-Level Physics

Momentum

Mark Scheme

Time available: 67 minutes
Marks available: 52 marks

1. (a) Conversion of 110 km h^{-1} to 31 m s^{-1} ✓

$= ½ \times 1.5 \times 10^3 \times$ *their conversion*^{2} with a consistent answer ✓

$(= 7(.2) \times 10^5)$

Allow ecf for incorrect or failure to carry out speed conversion

Expect answer to be calculated correctly and to 2+ sf.

Accept 700 kJ as 2 sf

2

(b) Component of velocity = 31 × cos (20)

OR

evidence of using momentum = mass × velocity (eg 1.5×10^3 × a velocity) ✓

$= 4.4 \times 10^4$ ✓

For unit only accept kg m s^{-1} **OR** N s ✓

Allow ecf for speed from part (a)

Accept 4.65×10^4 *kg m* s^{-1} *for max 2*

Use of 30.6 m s^{-1} *gives 43 kN s*

3

(c) (KE before collision = 700 kJ)

Speed (parallel to barrier) after (= 31 × cos 20) = 28.7 m s^{-1} ✓

KE after($= ½ \times 1.5 \times 10^3 \times 28.7^2$) = 618 kJ ✓

Change = 700 – 618 ✓ (= 82 kJ)

OR

Speed (perpendicular to barrier) after = 31 × sin 20 (= 10.5 m s^{-1}) ✓

Loss of KE (= ½ × 1.5 × 10^3 × 10.5^2) = 82 kJ ✓

Justification that total KE = KE due to speed parallel to barrier + KE due to speed perpendicular to barrier ✓

Allow ecf for speed from part (a)

Use of KE = $p^2/2m$ can gain full credit.

Allow ecf for momentum in part (b)

Final answer depends on extent to which candidate has rounded in earlier parts. Allow correctly evaluated solutions for full credit.

In this question, do not insist on final answer to 2+ sf.

If there is a suggestion that KE is a vector or can be resolved, do not award MP3.

3

(d) Evidence of work done = force × distance

Eg Force = 82 000 / 1.5 OR their value for part (c) ÷ part (a) ✓

Allow 80 kJ for energy

= 5.5 × 10^4 N✓

This is less than braking force – so yes. ✓

OR energy approach

- work done by barrier = 60 kN × 1.5 m ✓
- 90 kJ ✓
- which is > E_k of vehicle, so yes ✓

OR impulse argument

- evaluate time taken to stop, 0.26 s ✓
- impulse value leading to distance or force ✓
- conclusion consistent with correct method of calculation ✓

OR use of F = ma and suvat :

- F = ma leading to a = (-)40 m s^{-2} ✓
- suvat leads to 1.37 m ✓
- which is < 1.5 m, so yes ✓

General scheme for alternatives and reverse arguments is:

- *first step calculation*
- *subsequent calculation(s) leading to comparative value. Allow ecf for error in first step.*
- *conclusion consistent with correct method of calculation*

Alternative suvat method:

- *uses suvat to get a = 36.5 m s^{-2}*
- *uses F = ma*
- *which is <60 kN, so yes*

3

(e) (Steel barrier is better because)

Increase time of contact as material deforms ✓

Reference to impulse (= change in momentum = Ft) implies smaller force (on dummy) ✓

OR

Increasing stopping distance as material deforms ✓

Reference to work done (= Fs) implies smaller force (on dummy) ✓

Allow correct discussion leading to concrete barrier is worse.

Alternative second mark for either alternative can be awarded for correct reference to F = ma

2

[13]

2. (a) (Total) kinetic energy ✓

1

(b) Attempt to apply conservation of momentum ✓

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

1

16 000 × 2.8 – 12 000 × 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) × 10^4 ✓

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

OR

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

1

[8]

3. (a) 7.3(4) × 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

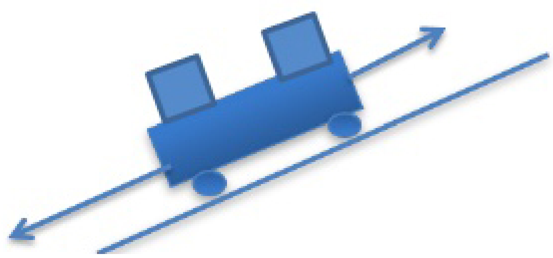
Must be clear about which ion candidate is discussing

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

3

[9]

4. (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]

5. (a) Attempt to determine area under graph or statement that area under needed or $0.5 \times 15 \times 10^{-3} \times 66$ ✓

0.495 (N s)✓

condone power of 10 error

2

(b) Momentum before = 0.045 × 7.1 = 0.320 (N s) down✓

Momentum after = 0.045 × 3.9 = 0.175 (N s) upwards✓

Change = 0.495 (N s) ✓

3

(c) Initial KE on impact = $0.5 \times 0.045 \times 7.1^2 = 1.13$ (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 = $0.3^3 \times 100$ (%) = 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]