PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 6: FURTHER MECHANICS

IMPULSE AND COLLISIONS IN 2D

SCORE	PERCENTAGE
/140	%

STEMUP

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Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A B *is not correct because these are base units of force* C *is not correct because these are not base units* D *is not correct because these are not base units*	$kg\ m\ s^{-1}$	**1**

Q2.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)	• attempts to find area under second peak (1) OR use of a suitable equation of motion OR equate $E = \frac{1}{2}mv^2$ and $\Delta E = mg\Delta h$ • height = 0.9 - 1.0 m (1)	Example of calculation: $h = \frac{1}{2} \times 4.2\ m\ s^{-1} \times (1.2-0.70)\ s = 1.0\ m$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	• use of $\Delta E = mg\Delta h$ (1) OR use of $E = \frac{1}{2}mv^2$ (1) • ΔE =0.59 J	Example of calculation: $E = 0.060\ kg \times 9.81 m\ s^{-2} \times (2.0 - 1.0) m$ $E = 0.59\ J$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	EITHER • finds gradient of middle section (1) • use of $F = ma$ (1) • $F = 64$ N (1) OR • reads two corresponding pairs of v and t from middle section of graph (1) • use of $F = \frac{m(v-u)}{\Delta t}$ (1) • $F = 64$ N (1)	Example of calculation: $F = \frac{(6.3+4.2)\ \text{m s}^{-1}}{(0.74-0.64)\ \text{s}} \times 0.060\ \text{kg} = 64\ \text{N}$	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(d)	Initial free-fall • gradient of both graphs is the same (1) Bounce section • the gradient of the soft ball graph is less (1) Second free-fall • gradient of the soft ball graph is the same as the first graph OR the gradient is the same as in the initial free-fall (1)	Accept the first line is the same Accept time for the bounce is longer	**(3)**

Q3.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Use of ½ $mv^2 = mgh$ **(1)** • $v = 2.43$ m s^{-1} **(1)**	Example of calculation: $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.30} = 2.43$ m s^{-1}	**2**
(ii)	• Use of impulse = change in momentum **(1)** • Recognises initial velocity is zero **(1)** • Hence $F = 0.923$ N **(1)** • Use of $l = \pi d$ **(1)** • Equates calculated value of F with BIl **(1)** • Hence I = 191 A **(1)**	Example of calculation: $Ft = mv - mu$ where $u = 0$ So $F = (0.019 \text{ kg} \times 2.43 \text{ m s}^{-1})/0.05 \text{ s} = 0.923$ N $l = \pi \times 0.048 \text{ m} = 0.151$ m $I = 0.923 \text{ N}/(0.032 \text{ T} \times 0.151 \text{ m}) = 191$ A	**6**

Q4.

Question Number	Answer	Mark
	C	**1**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	• Impulse is the product Ft which is area under this graph **(1)**		**1**

Q6.

Question Number	Answer	Mark
	D	1

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	An explanation that makes reference to the following: • air molecules make collisions with the puck and transfer momentum to the puck (1) • according to Newton's 2nd law the change of momentum creates a force on the puck (1) • the rate of change of momentum by air molecules colliding with bottom of puck is greater than that due to the collisions on the top of the puck (1) • the net (upward) force balances the weight of the puck <u>OR</u> the greater air pressure below the puck allows the puck to be supported. (1)		**(4)**

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>* (b)</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr></table></td><td>Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td></td></tr>
</table>

5 - 4	3
3 - 2	2
1	1
0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Indicative content:

- applying Newton's 3rd law one puck (A) exerts a force on the other puck (B) and vice versa (1)
- forces equal in magnitude and opposite and direction (1)
- forces act for same time (1)
- $F\Delta t_A = -F\Delta t_B$ (1)
- applying Newton's 2nd law $F\Delta t = \Delta p$ since F is a resultant force on each puck (1)
- total change in momentum = zero, so momentum is conserved (1)
  OR Δp for one puck = $-\Delta p$ for the other puck, so momentum is conserved

(6)

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)(i)	• resolve velocities to find forward/sideways component	(1)	Example of calculation: Forwards velocity components: $v\cos 30^\circ = 0.866\,v$; $2\cos 60^\circ = 1\,\text{m s}^{-1}$ $4m = m \times 0.866v + m \times 1$ $\therefore v = \frac{(4-1)\,\text{m s}^{-1}}{0.866} = 3.46\,\text{m s}^{-1}$	**(3)**
	• apply principle of conservation of momentum	(1)		
	• v = 3.46 m s^{-1}	(1)		
(c)(ii)	• use $KE = \frac{1}{2}mv^2$	(1)	Example of calculation: $KE_i = \frac{1}{2}m \times 4^2 = 8m$ $KE_f = \frac{1}{2}m \times 3.46^2 + \frac{1}{2}m \times 2^2$ $= 6m + 2m = 8m$	**(3)**
	• show that final KE is equal to initial KE	(1)		
	• elastic collisions conserve KE, so collision is elastic	(1)		

Q8.

Question Number	Answer	Mark
	B	1

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Attempt to determine an area **(1)** • Uses area = change of momentum **(1)** • velocity in range 28 – 33 ($m\,s^{-1}$) **(1)**	eg markings on the graph Example of calculation: Approximates area = triangle = (0.0005 s × 5500 N) / 2 Area = 1.375 Ns Velocity = 1.375 Ns / 0.046 kg = 29.1 ms^{-1}	**3**
(ii)	• Use of $s = ut + \frac{1}{2}at^2$ in vertical direction **(1)** • if s + then ut + and at^2 negative **(1)** **Or** if s – then ut – and at^2 positive • Use of velocity = distance / time in horizontal direction **(1)** • Correct component of velocity in each direction **(1)** • Distance = 76 m and comment such as yes it reaches the green. (ECF from bi) **(1)** Range of distance 70.5 m for b(i) $v = 28\ m\,s^{-1}$ to 93.6 m for $v = 33\ m\,s^{-1}$	Alt: Use of pythagorus to find resultant velocity Also accept conclusion based on a comparison of velocity values from (i) and (ii) Example of calculation: $7.5m = 29m\,s^{-1}\sin\theta 3.5s - \frac{1}{2} 9.81m\,s^{-2}3.5^2s^2$ $7.5m = 101.5\sin\theta - 60.1$ $\sin\theta = 67.6 / 101.5$ $\theta = 41.8°$ $29\ ms^{-1}\cos 41.8 = x / 3.5\ s$ $x = 75.7\ m$ Using the "show that" value: $7.5m = 30m\,s^{-1}\sin\theta 3.5s - \frac{1}{2}9.81m\,s^{-2}3.5^2s^2$ $7.5m = 105\sin\theta - 60.1$ $\sin\theta = 67.6 / 105$ $\theta = 40.1°$ $30\ ms^{-1}\cos 40.1 = x / 3.5\ s$ $x = 80.3\ m$	**5**

Mark Scheme

Q1.

Question number	Acceptable answers	Additional guidance	Mark
	B		1

Q2.

Question Number	Answer	Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) statement that indicates that the conservation of momentum does apply (1) the idea that the probe and tank move in opposite directions [accept move apart] **Or** the idea that the probe and tank experience equal and opposite forces (1) Probe and tank experience equal **changes** in momentum (in opposite directions) (1) Statement that indicates that (total) energy is conserved (1) Kinetic energy of the system increases (so speed increases) (1) (Some) chemical energy converted to KE (1)	6
	Total for question	6

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• units eV (energy) base units: kg m^2 s^{-2} **Or** base units of momentum: kg m s^{-1} **(1)** • divide energy by units of speed (c) m s^{-1} gives kg m s^{-1} which are units of momentum Or multiply units of momentum by speed (c) m s^{-1} to give units of energy kg m^2 s^{-2} **(1)**		**2**
(ii)	• resolves a y-component or x-component of electron momentum **(1)** • applies momentum conservation in x-direction or y-direction **(1)** • comparison of total momentum after **Or** momentum of proton after plus comment **(1)** Alternative: • draws a vector triangle	Example of calculation $p_y = 9.1\ (GeV/c)\sin 20 = 3.1\ GeV/c$ $p_x = 9.1\ (GeV/c)\cos 20 = 8.55\ GeV/c$ p_x of proton = 20 (GeV/c) - 8.55 (GeV/c) = 11.45 G $p_{proton} = \sqrt{3.1^2 + 11.45^2}$ = 11.86 GeV/c Alternative: p_y = 9.1 (GeV/c)sin20 = 3.1 GeV/c=11.9($\emptyset = 15.2$ So total p after = 11.9 GeV/c cos 15.2 + 9.1 (GeV/c)cos20	**3**
	• Uses cosine rule • Calculates angle from three sides = 20.4°	= 11.5 + 8.55 = 20.05 GeV/c	
(iii)	• (total) kinetic energy not conserved **(1)**		**1**

Q4.

Question Marks	Acceptable Answers	Additional guidance	Mark
	• Magnet accelerates ball (1) Or magnet increases ball's KE • Momentum is conserved in the collision(s) (1) • (Since collisions are elastic) KE conserved so third ball moves off with the same velocity/KE as incoming ball hit magnet with (1)	Marks can be gained by discussing either set of balls	3

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	An explanation that makes reference to the following: • air molecules make collisions with the puck and transfer momentum to the puck (1) • according to Newton's 2nd law the change of momentum creates a force on the puck (1) • the rate of change of momentum by air molecules colliding with bottom of puck is greater than that due to the collisions on the top of the puck (1) • the net (upward) force balances the weight of the puck <u>OR</u> the greater air pressure below the puck allows the puck to be supported. (1)		**(4)**

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Indicative content:

- applying Newton's 3rd law one puck (A) exerts a force on the other puck (B) and vice versa (1)
- forces equal in magnitude and opposite and direction (1)
- forces act for same time (1)
- $F\Delta t_A = -F\Delta t_B$ (1)
- applying Newton's 2nd law $F\Delta t = \Delta p$ since F is a resultant force on each puck (1)
- total change in momentum = zero, so momentum is conserved (1)
  OR Δp for one puck = $-\Delta p$ for the other puck, so momentum is conserved

(6)

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)(i)	• resolve velocities to find forward/sideways component	(1)	Example of calculation: Forwards velocity components: $v\cos 30^\circ = 0.866\,v$; $2\cos 60^\circ = 1\,\text{ms}^{-1}$ $4m = m \times 0.866v + m \times 1$ $\therefore v = \frac{(4-1)\,\text{ms}^{-1}}{0.866} = 3.46\,\text{ms}^{-1}$	**(3)**
	• apply principle of conservation of momentum	(1)		
	• v = 3.46 m s^{-1}	(1)		
(c)(ii)	• use $KE = \frac{1}{2}mv^2$	(1)	Example of calculation: $KE_i = \frac{1}{2}m \times 4^2 = 8m$ $KE_f = \frac{1}{2}m \times 3.46^2 + \frac{1}{2}m \times 2^2$ $= 6m + 2m = 8m$	**(3)**
	• show that final KE is equal to initial KE	(1)		
	• elastic collisions conserve KE, so collision is elastic	(1)		

Q6.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of momentum = mv	(1)	Example of calculation: $7.1(\text{g})u = 7.1(\text{g}) \times 0.9(\text{ms}^{-1}) \times \cos 8$ $+ 3.6(\text{g}) \times 1.4(\text{ms}^{-1}) \times \cos 10$ $u = \frac{(6.33 + 4.96)}{7.1}$ $u = 1.59 ms^{-1}$	(4)
	• See component(s) in x direction	(1)		
	• Uses momentum conservation	(1)		
	• u = 1.6 (m s^{-1})	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	• Use of $E_k = ½\,mv^2$	(1)	Allow ecf from b(i)	(2)
	• Value of Initial E_k = 9.0×10^{-3} (J) and Final $E_k = 6.4\times10^{-3}$ (J) (Show that value gives Initial $E_k = 1.42\times10^{-2}$ (J) allow ecf from (b)(i))	(1)	Example of calculation: Initial $E_k = ½ \times 7.1\times10^{-3}(\text{kg}) \times 1.59^2(\text{ms}^{-1})^2 = 9.0\times10^{-3}$ J Final $E_k = ½ \times 7.1\times10^{-3} \times 0.9^2 + ½ \times 3.6\times10^{-3} \times 1.4^2 = 6.4\times10^{-3}$ J	

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: Observation 1 • (the fraction of alpha scattering is less for aluminium) so the force of repulsion is less (at a given distance) **(1)** • therefore the charge on an aluminium nucleus is less than on gold nucleus **(1)** Observation 2 • (the E_k is less for scattered alpha for aluminium) so recoiling nucleus must have some/more kinetic energy **(1)** • The mass of an aluminium nucleus is less than mass of a gold nucleus **(1)**		**4**

Q2.

Question Number	Acceptable Answer	Additional Guidance	
	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The table shows how the marks should be awarded for indicative content and lines of reasoning. **IC points / IC mark / Max linkage mark available / Max final mark** **6** 4 2 **6** **5** 3 2 **5** **4** 3 1 **4** **3** 2 1 **3** **2** 2 0 **2** **1** 1 0 **1** **0** 0 0 **0**	Number of marks awarded for structure of answer and sustained line of reasoning Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout: 2 Answer is partially structured with some linkages and lines of reasoning: 1 Answer has no linkages between its points and is unstructured: 0	
	Indicative content: • (Collision takes place on an ice surface so) there is minimal friction **Or** External forces are negligible • Momentum is conserved in the collision • The momentum of stone A before the collision equals the momentum of (A and) B after the collision • Stone A must be at rest after the collision • All of the kinetic energy of stone A must have been transferred to stone B • Kinetic energy is conserved in an elastic collision		6

Q3.

Question Number	Answer	Mark
	C	1

Q4.

Question number	Acceptable answers	Additional guidance	Mark
	B		**1**

Q5.

Question Number	Answer		Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) statement that indicates that the conservation of momentum does apply	(1) 	
	the idea that the probe and tank move in opposite directions [accept move apart] **Or** the idea that the probe and tank experience equal and opposite forces	(1) (1)	
	Probe and tank experience equal **changes** in momentum (in opposite directions)	(1)	
	Statement that indicates that (total) energy is conserved	(1)	
	Kinetic energy of the system increases (so speed increases)	(1)	
	(Some) chemical energy converted to KE	(1)	**6**
	Total for question		**6**

Q6.

Question Number	Answer	Mark
	B	**1**

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• units eV (energy) base units: kg m^2 s^{-2} **Or** base units of momentum: kg m s^{-1} **(1)** • divide energy by units of speed (c) m s^{-1} gives kg m s^{-1} which are units of momentum Or multiply units of momentum by speed (c) m s^{-1} to give units of energy kg m^2 s^{-2} **(1)**		**2**
(ii)	• resolves a y-component or x-component of electron momentum **(1)** • applies momentum conservation in x-direction or y-direction **(1)** • comparison of total momentum after **Or** momentum of proton after plus comment **(1)** Alternative: • draws a vector triangle	Example of calculation $p_y = 9.1\ (GeV/c)\sin 20 = 3.1\ GeV/c$ $p_x = 9.1\ (GeV/c)\cos 20 = 8.55\ GeV/c$ p_x of proton = 20 (GeV/c) - 8.55 (GeV/c) = 11.45 G $p_{proton} = \sqrt{3.1^2 + 11.45^2}$ = 11.86 GeV/c Alternative: p_y = 9.1 (GeV/c)sin20 = 3.1 GeV/c=11.9($\emptyset = 15.2$ So total p after = 11.9 GeV/c cos 15.2 + 9.1 (GeV/c)cos20	**3**
	• Uses cosine rule • Calculates angle from three sides = 20.4°	= 11.5 + 8.55 = 20.05 GeV/c	
(iii)	• (total) kinetic energy not conserved **(1)**		**1**

Q8.

Question Marks	Acceptable Answers	Additional guidance	Mark
	• Magnet accelerates ball (1) Or magnet increases ball's KE • Momentum is conserved in the collision(s) (1) • (Since collisions are elastic) KE conserved so third ball moves off with the same velocity/KE as incoming ball hit magnet with (1)	Marks can be gained by discussing either set of balls	3

Q9.

Question Number	Answer	Mark
	C	**1**

Q10.

Question Number	Answer	Mark
	B	**1**

Mark Scheme

Q1.

Question Number	Answer		Mark
(a)	The wavelength (associated) with a particle/electron with a given momentum **Or** $\lambda = h/p$ all terms defined	(1) (1) (1) (1)	2
(b)(i)	Use of $E_k = eV$ Use of $E_k = p^2/2m$ **Or** use of $E_k = mv^2/2$ **and** $p = mv$ Momentum = 1.21×10^{-23} kg m s^{-1} Example of calculation $E_k = 1.6 \times 10^{-19}$ C× 500 V $p^2 = 2\,m\,E_k = 2 \times 9.11 \times 10^{-31}$ kg × $(1.6 \times 10^{-19} \times 500)$ J $p = 1.21 \times 10^{-23}$ kg m s^{-1}	(1) (1) (1)	3
(b)(ii)	Use of $\lambda = h/p$ $\lambda = 5.49 \times 10^{-11}$ m (ecf value of p from (i)) (show that value gives 6.63×10^{-11} m) Example of calculation $p = 6.63 \times 10^{-34}$ J s / 1.21×10^{-23} kg m s^{-1} $\lambda = 5.49 \times 10^{-11}$ m	(1) (1)	2
	Total for question		7

Q2.

Question Number	Acceptable Answers		Additional guidance	Mark
a	• fundamental – quarks and leptons • Baryons made of 3 q • Mesons made of quark and antiquark • 6 quark **Or** 6 leptons • Each particle has an antiparticle	(1) (1) (1) (1) (1)	MP2 and 3 could be given for a named particle and its quark composition Can be inferred if either set named	5

Question Number	Acceptable Answers		Additional guidance	Mark
b	• Use of $\Delta E = \Delta mc^2$ • Conversion of J to eV • mass = 120 GeV/c^2	(1) (1) (1)	Example of calculation: $E = 2.2\times10^{-25}\text{kg}\times(3.0\times10^{8})^2(\text{ms}^{-1})^2$ $E = 1.98\times10^{-8}\text{J}$ $E = 1.98\times10^{-8}\text{J}\div1.6\times10^{-19}\text{JeV}^{-1}$ $E = 124\times10^{9}\text{eV}$	3

Question Number	Acceptable Answers	Additional guidance	Mark
c(i)	• Energy (of protons) converted to mass (of Higgs) **Or** Energy is required to overcome electrostatic repulsion between protons (1) • Reference to $E = mc^2$ (can be written in any form) (1) • Because c^2 is very large (E must be large) **Or** Higgs particle is massive so needs a lot of energy to create it (1)	Alternative based on numerical values: Observation that Higgs mass is 120 GeV/c^2 This requires an energy of at least 120 GeV Each beam of protons would need an energy of at least 60 GeV	3
c(ii)	• Use of circumference = $2\pi r$ (1) • Use of $p = Bqr$ (1) • $p = 5.7 \times 10^{-15}$ Ns (1)	Example of calculation: $r = 27000 \div 2\pi$ $r = 4300$ m $p = 8.3\text{T} \times 1.6 \times 10^{-19}\text{C} \times 4300\text{m}$ $p = 5.7 \times 10^{-15}$ Ns	3
ciii	0 (1)	zero	1

Question Number	Acceptable Answers	Additional guidance	Mark
d	• High speeds **Or** relativistic (1) • Mass (of proton) increases (1) • **Or** this equation is only valid at non-relativistic speeds	Alt: speeds close to speed of light	2

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B *A is not correct because this is not dimensionally correct* *C is not correct because* $^{E_k}/_{2p} = {}^{v}/_{4}$ *D is not correct because this is not dimensionally correct*		1