Mark Scheme (Results)

Summer 2018

Pearson Edexcel GCE
In Mechanics M2 (6678/01)

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

Summer 2018
Publications Code 6678_01_1806_MS
All the material in this publication is copyright
© Pearson Education Ltd 2018

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate’s response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate’s response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

PEARSON EDEXCEL GCE MATHEMATICS

General Instructions for Marking

1. The total number of marks for the paper is 75.

2. The Edexcel Mathematics mark schemes use the following types of marks:

‘M’ marks
These are marks given for a correct method or an attempt at a correct method. In Mechanics they are usually awarded for the application of some mechanical principle to produce an equation.
e.g. resolving in a particular direction, taking moments about a point, applying a suvat equation, applying the conservation of momentum principle etc.
The following criteria are usually applied to the equation.

To earn the M mark, the equation
(i) should have the correct number of terms
(ii) be dimensionally correct i.e. all the terms need to be dimensionally correct
e.g. in a moments equation, every term must be a ‘force x distance’ term or ‘mass x distance’, if we allow them to cancel ‘g’ s.
For a resolution, all terms that need to be resolved (multiplied by sin or cos) must be resolved to earn the M mark.

M marks are sometimes dependent (DM) on previous M marks having been earned.
e.g. when two simultaneous equations have been set up by, for example, resolving in two directions and there is then an M mark for solving the equations to find a particular quantity – this M mark is often dependent on the two previous M marks having been earned.

‘A’ marks
These are dependent accuracy (or sometimes answer) marks and can only be awarded if the previous M mark has been earned. E.g. M0 A1 is impossible.

‘B’ marks
These are independent accuracy marks where there is no method (e.g. often given for a comment or for a graph)

A few of the A and B marks may be f.t. – follow through – marks.

3. General Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes.

- bod – benefit of doubt
- ft – follow through
- the symbol $\sqrt{}$ will be used for correct ft
- cao – correct answer only
- cso - correct solution only. There must be no errors in this part of the question to obtain this mark
- isw – ignore subsequent working
- awrt – answers which round to
- SC: special case
- oe – or equivalent (and appropriate)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- ∗ The answer is printed on the paper
- ⎣ The second mark is dependent on gaining the first mark

4. All A marks are 'correct answer only' (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.

6. If a candidate makes more than one attempt at any question:
   - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
   - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.

General Principles for Mechanics Marking

(But note that specific mark schemes may sometimes override these general principles)

- Rules for M marks: correct no. of terms; dimensionally correct; all terms that need resolving (i.e. multiplied by cos or sin) are resolved.

- Omission or extra g in a resolution is an accuracy error not method error.

- Omission of mass from a resolution is a method error.

- Omission of a length from a moments equation is a method error.

- Omission of units or incorrect units is not (usually) counted as an accuracy error.

- DM indicates a dependent method mark i.e. one that can only be awarded if a previous specified method mark has been awarded.

- Any numerical answer which comes from use of g = 9.8 should be given to 2 or 3 SF.

- Use of g = 9.81 should be penalised once per (complete) question.

  N.B. Over-accuracy or under-accuracy of correct answers should only be penalised *once* per complete question. However, premature approximation should be penalised every time it occurs.

- Marks must be entered in the same order as they appear on the mark scheme.

- In all cases, if the candidate clearly labels their working under a particular part of a question i.e. (a) or (b) or (c),……then that working can only score marks for that part of the question.

- Accept column vectors in all cases.

- Misreads – if a misread does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, bearing in mind that after a misread, the subsequent A marks affected are treated as A ft

- Mechanics Abbreviations

  M(A) Taking moments about A.

  N2L Newton's Second Law (Equation of Motion)

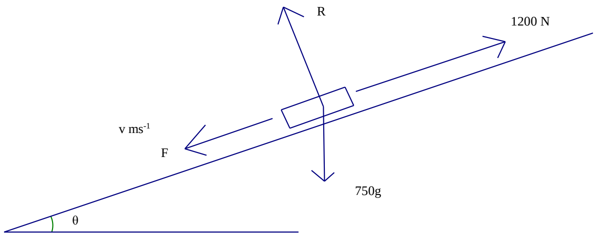
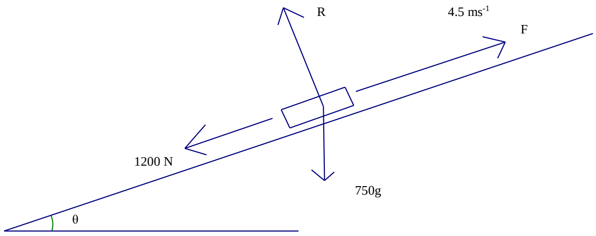
  NEL Newton's Experimental Law (Newton's Law of Impact)

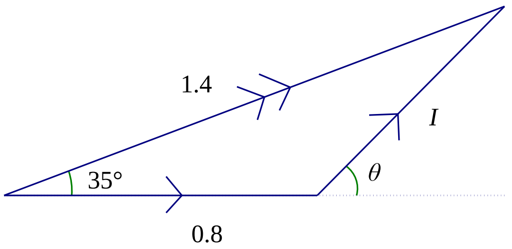
  HL Hooke's Law

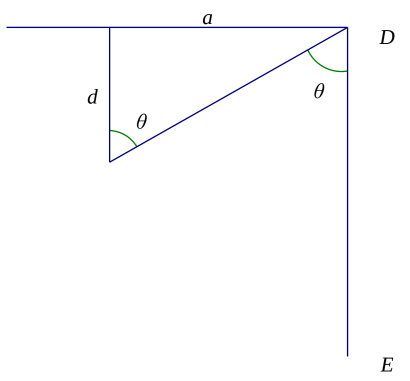
  SHM Simple harmonic motion

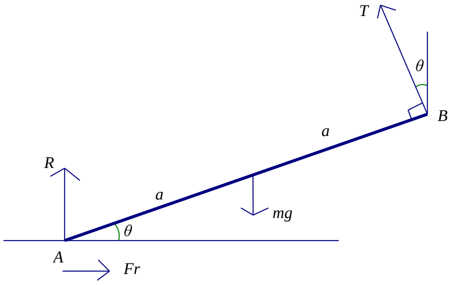
  PCLM Principle of conservation of linear momentum

  RHS, LHS Right hand side, left hand side

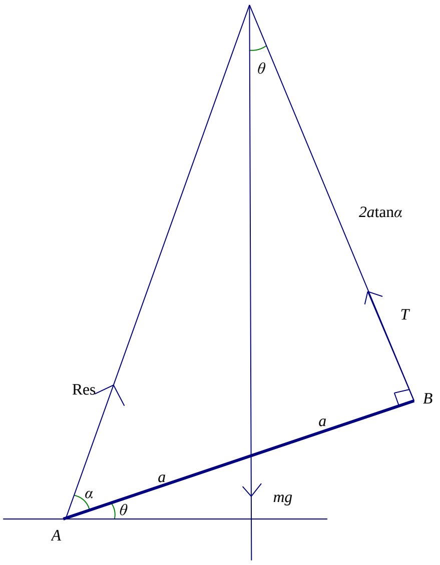
Q	Scheme	Marks	Notes
1a			
	Motion down the plane:	M1	Dimensionally correct. Condone sign errors and sin/cos confusion.
	$F + 750g\sin\theta = 1200$	A1	$\left(F + 450 = 1200\right)$
	Use of $P = Fv$: $F = \dfrac{9000}{v}$	B1	Award in (b) if not seen in (a)
	$\dfrac{9000}{v} + 750g \times \dfrac{3}{49} = 1200$		
	$v = \dfrac{9000}{750} = 12$	A1	
		(4)	
1b			
	$F = ma$: $F - \left(750g\sin\theta + 1200\right) = 750a$	M1	Dimensionally correct. Condone sign errors and sin/cos confusion.
	$\dfrac{9000}{4.5} - \left(750g \times \dfrac{3}{49} + 1200\right) = 750a$	A1	Unsimplified equation with at most one error
		A1	Correct unsimplified equation
	$a = 0.47$ (0.467) (m s^{-2})	A1	2 or 3 sf only not $\dfrac{7}{15}$
		(4)	
		[8]	

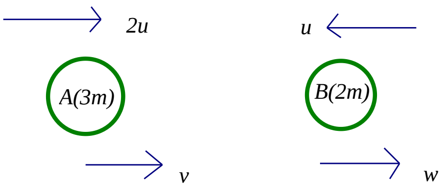
Q	Scheme	Marks	Notes
2a	Using column vectors or **i** and **j**: $\begin{pmatrix} I\cos\theta \\ I\sin\theta \end{pmatrix} = 0.2\begin{pmatrix} 7\cos 35 \\ 7\sin 35 \end{pmatrix} - 0.2\begin{pmatrix} 4 \\ 0 \end{pmatrix}$	M1	Must be subtracting. Need both components Could consider components separately
	$\left(= \begin{pmatrix} 0.347 \\ 0.803 \end{pmatrix} \right)$	A1	Correct unsimplified equation. Accept +/-
	$\lvert I \rvert = \sqrt{0.347^2 + 0.803^2}$	DM1	Use Pythagoras to find magnitude Dependent on the previous M1
	$\lvert I \rvert = 0.875$	A1	0.87 or better
		(4)	
a alt	Alternative using vector triangle  	M1	Allow with velocities rather than impulse/momentum
	Cosine rule: $\lvert I \rvert^2 = 1.4^2 + 0.8^2 - 2\times 1.4\times 0.8\times \cos 35°$	DM1 A1	Dependent on the previous M1
	$\lvert I \rvert = 0.875$ (N s) (0.87 or better)	A1	
		(4)	
2b	$\tan\theta = \dfrac{0.803}{0.347}$ $\left(\text{or } \cos\theta = \dfrac{0.347}{0.875}\right)$	M1	Trig ratio of a relevant angle (using velocities or impulse/momentum)
		A1ft	Correct expression for correct θ Ft on values from (a) Do not ISW
	$\theta = 66.6°$ (67)	A1	Or better from correct work.
		(3)	
b alt	Sine rule: $\dfrac{\sin\theta}{1.4} = \dfrac{\sin 35}{\lvert I \rvert}$	M1 A1ft	
	$\theta = 66.6°$ (67)	A1	Or better
		(3)	
		[7]	

Q	Scheme	Marks	Notes
3a	Mass ratios : $4a^2 : \frac{\pi a^2}{2} : a^2\left(4+\frac{\pi}{2}\right)$	B1	Or equivalent
	Distances relative to *BD*: $a, -\frac{4a}{3\pi}, (d)$	B1	Or equivalent . Condone sign errors
	Moments about *BD* (or a parallel axis)	M1	Dimensionally correct. All terms required. Condone sign errors. Accept in a vector equation.
	$4a^2 \times a + \frac{\pi a^2}{2} \times \frac{-4a}{3\pi} = \left(4+\frac{\pi}{2}\right)a^2 \times d$	A1	Correct unsimplified equation
	$a\left(4-\frac{4}{6}\right) = \left(4+\frac{\pi}{2}\right)d$		(Distance from *AE* = $\frac{(28+6\pi)a}{3(8+\pi)}$)
	$d = a \times \frac{10}{3} \times \frac{2}{(8+\pi)} = \frac{20a}{3(8+\pi)}$	A1	Obtain **given answer** from correct working. Condone -ve becoming positive with no explanation at the end
		(5)	
3b.			
	Use trig to find relevant angle	M1	Using the given value of *d*
	$\tan\theta = \frac{a}{d} = \frac{3(8+\pi)}{20}\left(=\frac{1}{0.598}\right)$	A1	Correct expression for required angle
	$\theta(=59.12....) = 59°$	A1	NB:The question asks for the nearest degree
		(3)	
		[8]	

Q	Scheme	Marks	Notes
4			
	M(A): $2aT = mga\cos\theta \qquad \left(T = \frac{1}{2}mg\cos\theta\right)$ M(B): $mga\cos\theta + Fr\times 2a\sin\theta = R\times 2a\cos\theta$	M1A1	First equation Need all terms. Condone sign errors and sin/cos confusion
	Resolve $\leftrightarrow$: $Fr = T\sin\theta\left(= \frac{1}{2}mg\cos\theta\sin\theta\right)$	M1A1	Second equation Need all terms. Condone sign errors and sin/cos confusion
	$\updownarrow$: $R + T\cos\theta = mg$	M1A1	Third equation Need all terms. Condone sign errors and sin/cos confusion
	Use $Fr = \mu R$: $\mu R = T\sin\theta$	B1	Condone correct inequality
	Form equation in μ and θ: $R = mg - \frac{1}{2}mg\cos\theta\cos\theta$ and $\mu R = \frac{1}{2}mg\cos\theta\sin\theta \quad \Rightarrow$	DM1	Eliminate T and R Dependent on first 3 M marks
	$\mu = \dfrac{\frac{1}{2}mg\cos\theta\sin\theta}{mg - \frac{1}{2}mg\cos\theta\cos\theta}$	DM1	Solve for μ Dependent on previous M
	$\mu = \dfrac{\cos\theta\sin\theta}{2-\cos^2\theta}$	A1	Obtain **given answer** from correct working Must explain if inequality becomes equality
		[10]	

Alt 1	Moments (about B): $mga\cos\theta + Fr\times 2a\sin\theta = R\times 2a\cos\theta$	M1	
		A1	Correct unsimplified
	Resolving (parallel to rod): $Fr\cos\theta + R\sin\theta = mg\sin\theta$	M2	
		A2	-1 each error
	Use of $Fr = \mu R$: $mg\cos\theta + \mu R\times 2\sin\theta = R\times 2\cos\theta$ $\mu R\cos\theta + R\sin\theta = mg\sin\theta$	B1	
	Form equation in μ and θ: $\frac{mg\sin\theta}{mg\cos\theta} = \frac{\mu R\cos\theta + R\sin\theta}{2R\cos\theta - 2\mu R\sin\theta}$ $\frac{\sin\theta}{\cos\theta} = \frac{\mu\cos\theta + \sin\theta}{2\cos\theta - 2\mu\sin\theta}$	DM1	
	Solve for μ : $2\cos\theta\sin\theta - 2\mu\sin^2\theta = \mu\cos^2\theta + \cos\theta\sin\theta$	DM1	
	$\mu = \frac{\sin\theta\cos\theta}{\cos^2\theta + 2\sin^2\theta} = \frac{\sin\theta\cos\theta}{2-\cos^2\theta}$	A1	Obtain **given answer** from correct working
	NB for alternatives using moments and resolving: e.g. Resolve $\leftrightarrow$: $Fr = T\sin\theta$ M(centre): $aT = a\cos\theta R - a\sin\theta Fr$		First equation M1A1 Sufficient equations to solve M2A2

Alt 2			3 concurrent forces
	$\tan(\theta+\alpha)=\dfrac{\tan\theta+\tan\alpha}{1-\tan\theta\tan\alpha}$	M1A1	
	$\tan\theta=\dfrac{a}{2a\tan\alpha}\ \Rightarrow\ \tan\alpha=\dfrac{1}{2\tan\theta}$	M1	
	$\tan(\theta+\alpha)=\dfrac{\tan\theta+\dfrac{1}{2\tan\theta}}{1-\tan\theta\times\dfrac{1}{2\tan\theta}}$ $=2\left(\dfrac{\sin\theta}{\cos\theta}+\dfrac{\cos\theta}{2\sin\theta}\right)$	M1A1 A1	
	$F=\mu R\ \Rightarrow$ $\mu=\dfrac{1}{\tan(\theta+\alpha)}$	B1 DM1	
	$=\dfrac{1}{2}\left(\dfrac{2\sin\theta\cos\theta}{2\sin^2\theta+\cos^2\theta}\right)=\dfrac{\cos\theta\sin\theta}{2-\cos^2\theta}$	DM1 A1	Obtain **given answer** from correct working
		(10)	

Q	Scheme	Marks	Notes
5a			
	CLM: $3m\times 2u - 2m\times u = 3mv + 2mw$ $(4u = 3v + 2w)$	M1A1	
	Impact law: $w - v = \frac{1}{3}(2u + u) = u$	M1A1	
	Solve for simultaneous equations for *w* or *v*: $3w - 3v = 3u\ ,\ \ 2w + 3v = 4u$ $5w = 7u\ ,\ w = \frac{7}{5}u$	DM1 A1	Dependent on both previous M marks **Must see working - Given Answer**
	$v = \frac{2}{5}u$	A1	Or equivalent. Must be positive
		(7)	
5b	Speed of B after collision with wall: $\frac{1}{2}\times\frac{7}{5}u = \frac{7}{10}u$	B1	Accept +/-
	Total time for either particle	B1	
	Equate the time travelled for each particle:	M1	
	$\frac{x}{\frac{7}{5}u} + \frac{y}{\frac{7}{10}u} = \frac{x-y}{\frac{2}{5}u}$	A1	Correct unsimplified
	$\frac{5x}{7u} + \frac{10y}{7u} = \frac{5x}{2u} - \frac{5y}{2u}$, $\quad 10x + 20y = 35x - 35y$	DM1	Dependent on previous M1
	$55y = 25x, \qquad y = \frac{5}{11}x$	A1	Or equivalent. 0.45*x* or better
		(6)	

Alt 1	Speed of B after collision with wall: $\frac{1}{2}\times\frac{7}{5}u=\frac{7}{10}u$	B1	Accept +/-
	Time of travel for B: $\frac{x}{\frac{7}{5}u}+\frac{y}{\frac{7}{10}u}=\frac{5x+10y}{7u}$	B1	
	Distance moved by A:	M1	Correct method for distance
	$=\frac{2}{5}u\times\left(\frac{5x+10y}{7u}\right)=\frac{2x+4y}{7}$	A1	Correct unsimplified
	$\frac{2x+4y}{7}+y=x$, $2x+4y+7y=7x$	DM1	Dependent on previous M1. Form equation in *x* and *y*
	$y=\frac{5}{11}x$	A1	Or equivalent. 0.45*x* or better
		(6)	
Alt 2	Speed of B after collision with wall: $\frac{1}{2}\times\frac{7}{5}u=\left(\frac{7}{10}u\right)$	B1	Accept +/-
	$x-$distance moved by $A=x-\frac{2}{5}u\times\frac{5x}{7u}=\frac{5}{7}x$	B1	Distance apart when *B* hits the wall
	Gap closing at $\frac{7}{10}u+\frac{2}{5}u=\frac{11}{10}u$		
	Time to collision: $\left(\frac{5}{7}x\right)\div\left(\frac{11}{10}u\right)=\frac{50x}{77u}$	M1A1	Use of $\frac{9x}{7}$ for $\frac{5x}{7}$ is M0
	Distance moved by *B*: $y=\frac{7}{10}u\times\frac{50x}{77u}=\frac{5}{11}x$	DM1 A1	Dependent on previous M1 Or equivalent. 0.45*x* or better
		(6)	
Alt 3	Speed of B after collision with wall: $\frac{1}{2}\times\frac{7}{5}u=\left(\frac{7}{10}u\right)$	B1	Accept +/-
	$x-$distance moved by $A=x-\frac{2}{5}u\times\frac{5x}{7u}=\frac{5}{7}x$	B1	Distance apart when *B* hits the wall
	Ratio of speeds 4:7	M1A1	
	Distance moved by *B*: $y=\frac{7}{11}\times\frac{5x}{7}=\frac{5}{11}x$	DM1 A1	Dependent on previous M1 Use of $\frac{9x}{7}$ for $\frac{5x}{7}$ is M0 Or equivalent. 0.45*x* or better
		(6)	
		[13]	

Alt 4	Speed of B after collision with wall: $\frac{1}{2}\times\frac{7}{5}u\left(=\frac{7}{10}u\right)$	B1	Accept +/-
	$x-$distance moved by $A = x-\frac{2}{5}u\times\frac{5x}{7u}=\frac{5}{7}x$	B1	Distance apart when *B* hits the wall
	Equate times for each particle to cover the residual distance. $\frac{5}{2u}\left(\frac{5x}{7}-y\right)=\frac{10}{7u}\times y$, $\frac{1}{2}\left(\frac{5x}{7}-y\right)=\frac{11}{7}y$	M1A1	Use of $\frac{9x}{7}$ for $\frac{5x}{7}$ is M0
	Distance moved by *B*: $y=\frac{5}{11}x$	DM1 A1	Dependent on previous M1 Or equivalent. 0.45x or better
		(6)	

Q	Scheme	Marks	Notes
6a	Differentiate **v**: $\mathbf{a} = (4-6t)\mathbf{i} + (-8+2t)\mathbf{j}$	M1A1	Anywhere in (a)
	Use of $\mathbf{F} = m\mathbf{a}$ and substitute $t = 3$: $\mathbf{F} = 0.5((4-6\times3)\mathbf{i} + (-8+2\times3)\mathbf{j}) = -7\mathbf{i} - \mathbf{j}$	DM1	Dependent on the first M1
	Use of Pythagoras' theorem:	DM1	Dependent on the first M1
			NB Could use Pythagoras and then use $\mathbf{F} = m\mathbf{a}$. 1st M1 – 1st step. 2nd M1 - 2nd step
	$\lvert\mathbf{F}\rvert = \sqrt{49+1} = \sqrt{50}\left(= 5\sqrt{2} = 7.07...\right)$	A1	7.1 or better
	For **v**, **i** component= **j** component: $\left(4t-3t^2\right) = \left(-40-8t+t^2\right)$	M1	With no incorrect equations in *t* seen
	Solve for *t*: $4t^2 - 12t - 40 = 0$, $\Rightarrow$ $t^2 - 3t - 10 = 0$ $(t-5)(t+2) = 0$, $t = 5$	DM1 A1	Dependent on the previous M, Must see method if solving an incorrect quadratic Only - could be implied by later rejection of -2
	$\mathbf{a} = (4-30)\mathbf{i} + (-8+10)\mathbf{j} = -26\mathbf{i} + 2\mathbf{j}$ (ms^{-2})	A1	Only
		(9)	
6b	Integrate **v**: $\mathbf{r} = \left(2t^2 - t^3 (+p)\right)\mathbf{i} + \left(-40t - 4t^2 + \frac{1}{3}t^3 (+q)\right)\mathbf{j}$	M1 A2	-1 ee
	$\mathbf{r}_1 = \mathbf{i} - 43\frac{2}{3}\mathbf{j}$, $\mathbf{r}_2 = -93\frac{1}{3}\mathbf{j}$ $\overrightarrow{AB} = \mathbf{r}_2 - \mathbf{r}_1$	DM1	$\left(\frac{131}{3}, \frac{280}{3}\right)$ Use limits in a definite integral or to evaluate a constant of integration Dependent on the previous M1
	$\overrightarrow{AB} = -\mathbf{i} - 49\frac{2}{3}\mathbf{j}\left(= -\mathbf{i} - \frac{149}{3}\mathbf{j}\right)$	A1	49.7 or better
		(5)	
		[14]	

Q	Scheme	Marks	Notes
7a	Horizontal distance: $x = u\cos\alpha t$	B1	$\frac{1}{\sqrt{5}}ut$
	Vertical distance: $y = u\sin\alpha t - \frac{1}{2}gt^2$	M1A1	$\frac{2}{\sqrt{5}}ut - \frac{1}{2}gt^2$ Condone sign errors and sin/cos confusion
	$y = u\sin\alpha \times \frac{x}{u\cos\alpha} - \frac{g}{2}\times\left(\frac{x}{u\cos\alpha}\right)^2$ $= x\tan\alpha - \frac{gx^2}{2u^2}\times\frac{1}{\cos^2\alpha} = 2x - \frac{gx^2}{2u^2}\times\frac{1}{1/5}$	DM1	Substitute for t and α Dependent on previous M1
	$= 2x - \frac{5g}{2u^2}x^2$	A1	Obtain **given answer** from exact working
		(5)	
7b	$x = 36, y = 0$: $0 = 2 - \frac{5g}{2u^2}\times 36$,	M1	Use given equation or a complete method using *suvat* to find *u*.
	$u^2 = \frac{5g\times 36}{4}$, $u = 21$ (m s^{-1})	A1	Accept $\sqrt{45g}$
		(2)	
7c	Min speed $= u\cos\alpha$	M1	($u\cos\alpha = 21\times\frac{1}{\sqrt{5}} = 9.39$ (m s^{-1})) Consistent with their B1 in (a)
	Minimum KE: $\frac{1}{2}\times 0.3\times(u\cos\alpha)^2 = \frac{0.3}{2}\left(\frac{21}{\sqrt{5}}\right)^2 = 13.2$ (13) (J)	DM1 A1	Dependent on previous M1
		(3)	
7c alt	Max ht when $\frac{dy}{dx} = 0$, $x = \frac{2u^2}{5g}(=18)$	M1	Or from $\frac{1}{2}\times 36$ (symmetry)
	Conservation of energy: $\frac{1}{2}mu^2 - mgh = \frac{1}{2}mv^2$	M1	
	$= \frac{1}{2}\times 0.3\times 21^2 - 0.3\times g\times\frac{2\times 21^2}{5g}$ $= 13.2$ (J)	A1	
		(3)	

Q	Scheme	Marks	Notes
7d	Gradientof trajectory at B $=-\frac{1}{2}$	B1	Accept $\frac{-1}{\tan\alpha}$
	Differentiate and equate : $\frac{\mathrm{d}y}{\mathrm{d}x}=2-\frac{5g}{u^2}x=-\frac{1}{2}$	M1A1	(their u)
	solve for x: $-\frac{1}{2}=2-\frac{5g}{u^2}x$, $\frac{5}{2}=\frac{5gx}{u^2}$	DM1	Dependent on previous M1
	$x=\frac{21^2}{2g}=22.5\ (23)\ (\text{m})$	A1	
		(5)	
7d alt1	Gradient of trajectory at B $=-\frac{1}{2}$	B1	Accept $\frac{-1}{\tan\alpha}$
	Use components of velocity: $-\frac{1}{2}=\frac{u\sin\alpha-gt}{u\cos\alpha}$	M1	
	$t=\frac{u\sin\alpha+\frac{1}{2}u\cos\alpha}{g}\left(=\frac{105}{2g\sqrt{5}}\right)$	A1	$(t=2.40)$
	Horizontal distance: $u\cos\theta t=22.5\ (23)\ (\text{m})$	DM1 A1	Dependent on previous M1
		(5)	
7d alt2	Gradient of trajectory at B $=-\frac{1}{2}$	B1	Can be implied by downward velocity $\frac{21\sqrt{5}}{2}$ or $\frac{u\cos\alpha}{\tan\alpha}$
	$v_y=-\frac{1}{2}\times21\times\frac{1}{\sqrt{5}}$, $-\frac{21}{2\sqrt{5}}=21\times\frac{2}{\sqrt{5}}-gt$	M1	Use *suvat* to find t
	$t=\frac{\frac{5}{2}\times\frac{21}{\sqrt{5}}}{g}(=2.39)$	A1	
	Horizontal distance: $u\cos\theta t=22.5\ (23)\ (\text{m})$	DM1	Dependent on previous M1
		A1	
		(5)	
7d alt3	$\begin{pmatrix}u\cos\alpha\\u\sin\alpha\end{pmatrix}\cdot\begin{pmatrix}u\cos\alpha\\u\sin\alpha-gt\end{pmatrix}=0$	B1	Scalar product = 0
	$u^2\left(\cos^2\alpha+\sin^2\alpha\right)-u\sin\alpha gt=0$ $\Rightarrow u=\sin\alpha.gt$	M1A1	Must have –gt in second vector Solve for t
	Horizontal distance: $u\cos\alpha.t=u\cos\alpha\times\frac{u}{g\sin\alpha}=\frac{21^2}{2g}=22.5$	M1A1	
		(5)	
		[15]	

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London, WC2R 0RL, United Kingdom