Mark Scheme (Results)

Summer 2014

Pearson Edexcel International A Level in Mechanics 2 (WME02/01)

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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.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

PEARSON EDEXCEL IAL 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 $\surd$ 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. 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.

6. 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.

Question Number	Scheme	Marks
1a	$v = \int a\mathrm{d}t = \int 2t - 3\mathrm{d}t = t^2 - 3t\,(+C)$	M1A1
	$t = 0, v = 2 \Rightarrow C = 2 \quad v = t^2 - 3t + 2$	M1A1
		(4)
1b	$v = 0$	M1
	$(t-1)(t-2) = 0$	M1
	$t_1 = 1, \ t_2 = 2$	A1
		(3)
1c	$s = \int_1^2 t^2 - 3t + 2\mathrm{d}t = \left[\frac{1}{3}t^3 - \frac{3}{2}t^2 + 2t\right]_1^2$	M1A1
	$= \left(\frac{8}{3} - 6 + 4\right) - \left(\frac{1}{3} - \frac{3}{2} + 2\right)$ or $= \frac{1}{3}(8-1) - \frac{3}{2}(4-1) + 2(2-1)$	**DM**1
	Distance = $\frac{1}{6}$, 0.17 or better (m) (must be positive)	A1
		(4)
		[11]

Notes for Question 1

Question 1(a)

First M1 for attempt to integrate (one power increasing by 1)

N.B. They may use definite integrals: $\int_2^v \mathrm{d}v = \int_0^t 2t - 3\mathrm{d}t$

First A1 for a correct integral, without *c*

Second M1 for using *t*=0, *v*=2 to find a *c* value or substituting their limits

Second A1 for answer. ('*v* =' not needed)

Question 1(b)

First M1 for setting their *v* expression equal to zero.

Second M1 for solving for *t* (must be a quadratic) (This mark can be implied by two correct answers)

A1 for both answers.

Question 1(c)

First M1 for attempt to integrate their *v* (all powers increasing by 1)

First A1 for a correct integral (**NOT ft**), without *c*

Second M1, **dependent on first M1**, for substituting their *t* values and subtracting (either way round)

Second A1 for answer (must be positive) ; accept 0.17 or better.

N.B. If they go on and add or subtract some other distance it's M0.

Question Number	Scheme	Marks
2a	Equation of motion: $F + 1000g\sin\theta + 250g\sin\theta - 300 - 100 = 1250a$	M1A2
	$F + 612.5 - 400 = 1250a = 250$	
	$F = 37.5\,(\text{N})$	M1
	Power $= Fv = 37.5 \times 25 = 940$ W to 2 s.f. (938 W)	M1A1
		(6)
2b	Motion of trailer: $T - 100 + 250g\sin\theta = 250a$	M1A2
	$T = 27.5\,(\text{N})$ or 28 (N)	A1
		(4)
Alt 2b	Motion of car: $F + 1000g\sin\theta - T - 300 = 1000a$	M1A2 ft
	$T = 27.5\,(\text{N})$ or 28 (N)	A1
		(4)
		[10]

Notes on Question 2

Question 2(a)

(Deduct only 1 mark in **whole question** for not giving an answer to either 2 sf or 3 sf, following use of g = 9.8, or for use of g = 9.81) **Deduct the final A mark in whichever part of the question it first occurs.**

N.B. Use the value of the mass (1250, 1000 or 250) that is used in an equation to decide which part of the system the equation is for.

First M1 for $F = ma$ along the plane (up or down) for whole system, with usual rules ; allow even if a nor sin θ substituted, to produce an equation in F only (i.e. no T terms) **N.B.** They could use the equation(s) for the car and trailer to either find or eliminate T to produce this equation.
First A2 for the equation. (-1 each error.) Omission of g is an A error.
N.B. If they group two terms together in the whole system equation, penalise any errors for each part
e.g. + 400 for the resistance would count as 2 errors (+ 100 and +300)
or $1250\sin\theta$ for the combined weight component would count as 2 errors (g omitted twice)
Second M1(independent) for producing a value for F
Third M1 for (their F x 25)
Third A1 for 940 (w) or 938 (w) oe.

Question 2(b)

N.B. Use the value of the mass (1250, 1000 or 250) that is used in an equation to decide which part of the system the equation is for.

First M1 for $F = ma$ along the plane (up or down) for either car or trailer, with usual rules ; allow even if a nor sin θ (nor F in car equation) substituted
First A2 for the equation. (-1 each error.) (**ft** on their F)
Third A1 for 28 (N) or 27.5(N)

Question Number	Scheme	Marks
3a	Moments about A: $W \times 2a\cos 30 = T\cos 60 \times 2.5a$	M1A1
	$T = \dfrac{2W\sqrt{3}/2}{2.5 \text{ x } 1/2} = \dfrac{4W\sqrt{3}}{5}$ **ANSWER GIVEN**	A1
		(3)
3b	Horizontally: $(H =) \pm T\cos 60$	M1A1
	Vertically: $(V =) \pm (W - T\cos 30)$	M1A1
	$\lvert R\rvert = \dfrac{W}{5}\sqrt{1+12} = \dfrac{\sqrt{13}}{5}W$ ($0.72W$ or better)	**DM1**A1
		(6)
	OR: **Components along the rod (X) and perpendicular to the rod (Y)**	
	$\pm X = T\cos 30 - W\cos 60 \quad (= \dfrac{7W}{10})$	M1A1
	$\pm Y = W\cos 30 - T\cos 60 \quad (= \dfrac{\sqrt{3}W}{10})$	M1A1
	$\lvert R\rvert = \dfrac{W}{10}\sqrt{49+3} = \dfrac{\sqrt{13}}{5}W$ oe	**DM1**A1
		(6)
		[9]

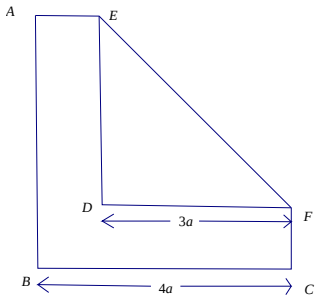
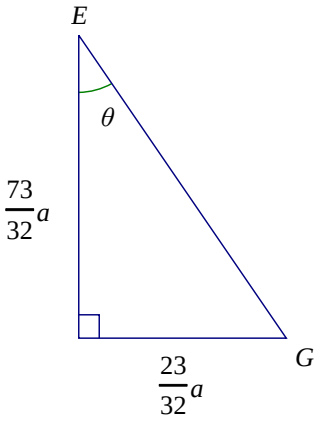
Notes on Question 3

Question 3(a) **N.B.** Extra g's are A errors not M errors.
First M1 is for producing an equation in T and W *only*, usually by taking moments about A (condone consistent missing 'a' s).
First A1 for a correct equation; trig ratios do not need to be evaluated.

Second A1 for **the given answer correctly obtained** (trig ratios do need to be evaluated in surd form but allow cancelling of 2's)

Question 3(b)
First M1, with usual rules, for producing horizontal cpt; could be X = or $R\cos\alpha$ = in terms of T and/or W only. (**N.B**. They may use 2 equations to do this)
First A1 for a correct expression (T does not need to be substituted)
Second M1, with usual rules, for producing vertical cpt; could be Y = or $R\sin\alpha$ = in terms of T and/or W only (**N.B**. They may use 2 equations to do this)
Second A1 for a correct expression (T does not need to be substituted)
Third M1**, dependent on previous two M's**, for solving for *R in terms of W only ,usually squaring and ADDING and square rooting*
Third A1 for $(W\sqrt{13})/5$ or $0.72W$ or better

Alternative using Triangle of Forces:
First M1 for attempt at cos rule: $R^2 = W^2 + T^2 - 2TW\cos 30^o$
First A1 if correct
Second M1 for substituting for T and $\cos 30^o$ (either surd or decimal)
Second A1 for a correct equation
Third M1, dependent on previous two M's, for solving for R
Third A1 for $(W\sqrt{13})/5$ or $0.72W$ or better

Question Number	Scheme		Marks
4a			
	Mass ratios (must add up to $16a^2$) e.g. $3(a^2)$, $4(a^2)$, $4.5(a^2)$, $4.5(a^2)$		B1
	One correct distance e.g. $0.5a$ or $2a$ or $2a$ or $2a$		B1
	Moments about AB: $16\overline{x} = (3 \times 0.5a) + (4 \times 2a) + (4.5 \times 2a) + (4.5 \times 2a)$		M1A2
	$16\overline{x} = \frac{55}{2}a$		
	$\overline{x} = \frac{55}{32}a$ **ANSWER GIVEN**		A1
			(6)
4b		$\overline{y} = \frac{55}{32}a$ seen or implied	B1
		$\tan\theta = \pm\left(\frac{\frac{55a}{32} - a}{4a - \overline{y}}\right)$ oe	M1A1
		$\theta = 17^\circ, 17.5^\circ$ or better	A1
			(4)
			[10]

Notes on Question 4

Question 4(a)

First B1 for appropriate mass ratios i.e. MUST be split into triangles and rectangles (can be numbers but must add to 16 (a^2)) i.e. this mark cannot be awarded if they haven't got 16 $\bar{x}$ in their 'moments' equation.
Second B1 for any single correct appropriate distance from *AB*
First M1 for 'moments' about *AB* or any other parallel line for their split.
A2 for correct equation (-1 e.e.o.o) (A0 if not split into triangles and rectangles)
Third A1 for **given answer**
N.B. If masses don't add to 16(a^2) then can score max B0B1M1A0A0A0

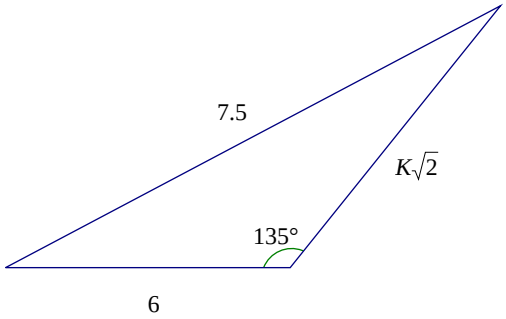
Question 4(b)

B1 for $\bar{y} = \frac{55a}{32}$ seen or implied (i.e. symmetry)

M1 for $\tan\theta = \pm\left(\frac{\frac{55a}{32} - a}{4a - \frac{55a}{32}}\right)$ oe $\left(= \frac{\frac{23a}{32}}{\frac{73a}{32}}\right)$ **or reciprocal**

First A1 for a correct numerical expression
Second A1 for 17^o, 17.5^o or better (in radians: 0.31 or better)

N.B. Instead of using $(4a - \bar{y})$ to find $\frac{73a}{32}$, they may start again to find distance of *G* from *AE*. Then $\frac{73a}{32}$ scores the B1 and if their value is used correctly, can score M1.

Question Number	Scheme	Marks
5	**i** direction: $K = 0.5(15\cos\theta - 12)$ **or** $K = 0.5v_1 - 6$	M1A1
	j direction: $K = 0.5 \text{ x } 15\sin\theta$ **or** $K = 0.5v_2$	M1A1
	$(12+2K)^2 + (2K)^2 = 15^2$	**DM**1
	$K = 1.37....$	A1
	, $\theta = 10.6°$ (10.550.) **or** , $\theta = 10.6°$ (10.5500..)	A1
		(7)
5 alt (i)	**i** direction: $K = 0.5(15\cos\theta - 12)$	M1A1
	j direction: $K = 0.5 \text{ x } 15\sin\theta$	M1A1
	$6 = 7.5(\cos\theta - \sin\theta)$	**DM**1
	$K = 1.37....$	A1
	$\theta = 10.6°$ (10.5500…)	A1
		(7)
5 alt (ii)		
	Sine rule: $\frac{\sin 135}{7.5} = \frac{\sin(45-\theta)}{6}$	M1A1
	$\frac{K\sqrt{2}}{\sin\theta} = \frac{7.5}{\sin 135}$	M1A1
	$K = 1.37....$	M1A1
	$\sin(45-\theta) = 0.5656.....$, $\theta = 10.6°$ (10.5500…)	A1
		(7)
		[7]

Notes on Question 5

Question 5

$K(\mathbf{i} + \mathbf{j}) = 0.5((15\cos\theta\,\mathbf{i} + 15\sin\theta\,\mathbf{j}) - 12\mathbf{i})$ (No marks until they separate the *x* and *y* directions)
No marks if the 15 is not resolved.
No marks if their equation is a mixture of vectors and scalars.
For all methods, irrespective of the order in which they are found, the 3rd A mark is for *K* and the 4th A mark is for θ.

First M1 for using imp-mom in the *x*-direction (MUST include mass for the M mark) Condone sign errors and allow **i**'s on both sides
First A1 for $K = 7.5\cos\theta - 6$ oe e.g. $K = 0.5v_1 - 6$ (NO **i**'s now)
Second M1 for using imp-mom in the *y*-direction (MUST include mass for the M mark) Condone sign errors and allow **j**'s on both sides
Second A1 for $K = 7.5\sin\theta$ oe e.g. $K = 0.5v_2$ (NO **j**'s now)
N.B. If they mix vectors and scalars in the *x*-dir equation to get a wrong *K* value, it's M0A0 but they can still score M1A1 for a correct equation in the *y*-dir, using their wrong *K* value.
Then,
either
Third M1 , dependent on both previous M marks, for using $\cos^2\theta + \sin^2\theta = 1$ to eliminate θ or using the magnitude to obtain: $(6+K)^2 + K^2 = 7.5^2$ oe
Third A1 for $K = (3\sqrt{34} - 12)/4 = 1.4, 1.37$ or better
Fourth A1 for $= 11^o, 10.6^o$ or better
or
Third M1 , dependent on both previous M marks, for eliminating *K* to give
$15\cos\theta - 12 = 15\sin\theta$
Third A1 for $K = (3\sqrt{34} - 12)/4 = 1.4, 1.37$ or better
Fourth A1 for $\theta = 11^o, 10.6^o$ or better

Alternative using a vector triangle
First M1 for applying sine rule
First A1 for $\sin 135 / 7.5 = \sin(45 - \theta) / 6$
Second M1 for applying sine rule
Second A1 for $K\sqrt{2} / \sin\theta = 7.5 / \sin 135$
Third M1 for solving for θ
Third A1 for $K = (3\sqrt{34} - 12)/4 = 1.4, 1.37$ or better
Fourth A1 for $\theta = 11^o, 10.6^o$ or better

Question Number	Scheme	Marks
6a	CLM: $3mu = 3mv + kmw \qquad (3u = 3v + kw)$	M1A1
	Impact: $w - v = \frac{1}{9}u \qquad (3w - 3v = \frac{1}{3}u)$	M1A1
	$\frac{10}{3}u = w(k+3)$	**DM1**
	$w = \frac{10u}{3(k+3)}$ **ANSWER GIVEN**	A1
		(6)
6b	$v = w - \frac{u}{9} = \frac{10u}{3(3+k)} - \frac{u}{9} < 0 \qquad v_P = \frac{u(27-k)}{9(k+3)} < 0$	M1**A1ft**
	$k > 27$	A1
		(3)
6c	$k = 7 \Rightarrow w = \frac{u}{3}$	B1
	CLM: $7 \times \textit{their}\ w = 7.5x$	M1
	$x = \frac{14u}{45}$	
	KE lost = $\frac{1}{2} \times 7m \times \frac{u^2}{9} - \frac{1}{2} \times 7.5m \times x^2$	M1A1
	$= \frac{7}{270}mu^2$	A1
		(5)
		[14]

Notes for Question 6

Question 6(a) N.B. Throughout this question ignore their diagram if this helps the candidate.
First M1 for CLM, correct no. of terms etc condone sign errors
First A1 for a correct equation
Second M1 for NIL, correct way up, condone sign errors
Second A1 for a correct equation (consistent v_P and v_Q with their momentum equation)
Third M1 for eliminating v_P
Third A1 for **given answer**

Question 6(b)
M1 for finding v_P
First **A1 ft** on the direction of their v_P, (look at their diagram and/or their equations)
for setting up an appropriate inequality **using their expression for v_P**
Second A1 for $k > 27$

Question 6(c)
B1 for $v_P = {}^1/_3\, u$ (seen or implied.)
First M1 for CLM, $7u/3 = 7.5\, x$
Second M1(independent) for ± (KE Loss of Q – KE gain of R) = ± **(** ½ $7m(u/3)^2$ – ½ $7.5m$ *(their* $x)^2$)
N.B. Allow M1 if m's omitted
First A1 for a correct unsimplified expression for the difference in either order, in m and u only
Second A1 for $7mu^2 / 270$ oe $0.026\, mu^2$ or better

Question Number	Scheme	Marks
7a	Energy: $\frac{1}{2}m.4^2 + mgh = \frac{1}{2}m.7^2$	M1A2
	$h = \frac{49-16}{2g} = 1.7$ (m) (1.68 m)	A1
		(4)
7b	Horizontal speed: $2.5 = 4\cos\alpha$	M1A1
	$\alpha = \cos^{-1}\left(\frac{5}{8}\right) =$ 51°, 51.3° or better	A1
		(3)
7c	Vertical speed at B $= \sqrt{7^2 - 2.5^2}\ (= 6.54)$	M1A1
	$v = u + at$: - 6.54… $= 4\sin\alpha - gt$	M1A1
	($t = 0.986$ s (0.99))	A1
	Horizontal distance $= 2.5t = 2.5$ or 2.46 (m) $((4\cos\alpha)t)$	M1A1
		(7)
		[14]
	Alternative 1	
	$s = ut + \frac{1}{2}at^2$: -1.68.. = 3.12…T – 4.9 T^2	M1 A1
	Solving $T = \frac{-3.122 \pm \sqrt{3.12^2 - 4 \text{x } 4.9 \text{ x } (-1.68)}}{2 \text{ x } 4.9}$	M1 A1
	($T = 0.986$ s (0.99))	A1
	Horizontal distance $= 2.5t = 2.5$ or 2.46 (m) $((4\cos\alpha)t)$	M1A1
		(7)
		[14]

Notes for Question 7

(Deduct only 1 mark in **whole of question 7** for not giving an answer to either 2 sf or 3 sf, following use of g = 9.8, or for use of g = 9.81) **Deduct the final A mark in whichever part of the question it first occurs.**

Question 7(a)

First M1 for use of conservation of energy (correct no. of terms) (allow if all *m*'s cancelled)
First A1 for PE term
Second A1 for KE terms
Third A1 for 1.7 (m) or 1.68 (m) (must be positive) (165/98 A0)
(allow h = - 1.68 obtained and then changed to (+)1.68)
N.B. Clear use of $v^2 = u^2 + 2as$ instead of energy is M0

Question 7(b)

First M1 for $2.5 = 4 \cos \alpha$ (with usual rules i.e. also allow $2.5 = 4\sin \alpha$),
First A1 for a correct equation
Second A1 for 51^o, 51.3^o or better (since no g involved)

Question 7(c)

Either

First M1 for v_B ($\uparrow$) = $\sqrt{(7^2 - 2.5^2)}$
First A1 ½ $\sqrt{171} = 6.54$
Second M1 for use of $v = u + at$: (4 must be resolved and v must be a vertical component (or attempt at one) $v = 7$ or $v = 2.5$ is M0
Second A1 for - 6.54 = $4\sin \alpha$ - gT
Third A1 for $T = 0.986..$ seen or implied

Or

First M1 for use of $s = ut + ½ at^2$ (4 must be resolved)
First A1 $-1.68.. = 3.122..T - 4.9 T^2$
Second M1 for solving a **THREE TERM** quadratic (**This M mark and the next A mark can be implied by a correct value for *t*, but if their *t* is wrong , then you must see a clear attempt to solve the quadratic using the formula)**
Second A1 for a correct expression
Third A1 for $T = 0.986..$ seen or implied

Then:
Third M1 for 2.5 x *their T* (must have found a value for *T) or* 4cos (their α) x their *T*
Fourth A1 for 2.5 (m) or 2.46 (m)

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