Pearson Edexcel

Mark Scheme (Results)

October 2020

Pearson Edexcel International Advanced Level In Mechanics M2 (WME02/01)

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October 2020
Publications Code WME02_01_2010_MS

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 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: Method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
- **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
- **B** marks are unconditional accuracy marks (independent of M marks)
- Marks should not be subdivided.

3. 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)
   - d… or dep – dependent
   - indep – independent
   - dp decimal places
   - sf significant figures
   - $\ast$ The answer is printed on the paper or ag- answer given
   - $\llcorner$ or d… 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.

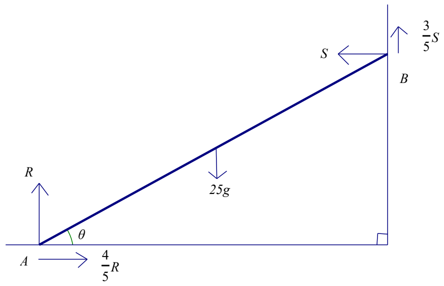
- Misreads – if a misread does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, bearing in mind that after a misread, the subsequent A marks affected are treated as A ft

- 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.

Question Number	Solution	Marks	Notes
1.	$\mathbf{I} = 2[\lambda\mathbf{i} + \lambda\mathbf{j} - 5\mathbf{i} - 3\mathbf{j}]$	M1	Use of $\mathbf{I} = m(\mathbf{v} - \mathbf{u})$
	$= 2(\lambda - 5)\mathbf{i} + 2(\lambda - 3)\mathbf{j}$	A1	Any equivalent form
	$\lvert I \rvert = \sqrt{40} \Rightarrow (\lambda - 5)^2 + (\lambda - 3)^2 = 10$	M1	Correct use of Pythagoras and their impulse to form an equation in λ
	$\lambda^2 - 8\lambda + 12 = 0 \Rightarrow \lambda = 2$ or $\lambda = 6$	DM1	Solve to find both values for λ. Dependent on the 2 preceding M marks
	$\mathbf{I} = -6\mathbf{i} - 2\mathbf{j}$ or $\mathbf{I} = 2\mathbf{i} + 6\mathbf{j}$ $(a = -6, b = -2$ or $a = 2, b = 6)$	A1	And no others
		(5)	
	Alternative working:		
	$\mathbf{I}(= a\mathbf{i} + b\mathbf{j}) = 2(\mathbf{v} - (5\mathbf{i} + 3\mathbf{j}))$	M1A1	
	$\mathbf{v} = \frac{a+10}{2}\mathbf{i} + \frac{b+6}{2}\mathbf{j} \quad \Rightarrow \quad (\Rightarrow a + 10 = b + 6)$		
	$a^2 + b^2 = 40 \Rightarrow b^2 - 4b - 12 = 0$ or $a^2 + 4a - 12 = 0$	M1	Correct use of Pythagoras and impulse to form an equation in a or b Any equivalent form
	$b^2 - 4b - 12 = 0 \quad \Rightarrow b = 6$ or $b = -2$	DM1	
	$\mathbf{I} = -6\mathbf{i} - 2\mathbf{j}$ or $\mathbf{I} = 2\mathbf{i} + 6\mathbf{j}$	A1	Or simplified equivalent
		[5]	

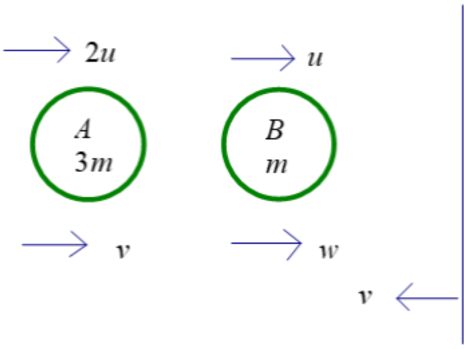
Question Number	Solution	Marks	Notes
2	Driving force $=\dfrac{3P}{12}$	B1	Use of $P = Fv$ Allow for $\dfrac{P}{12}$ in second equation if not awarded here
	Motion up the hill $F - R - W\sin\theta = 0$	M1	Need all terms. Condone sign errors and sin/cos confusion.
	$\dfrac{3P}{12} - R - \dfrac{9000}{15} = 0$ $\left(\dfrac{3P}{12} - R = 600\right)$	A1	Correct substituted equation Any equivalent form
	Motion down the hill $F + W\sin\theta - R = \dfrac{9000}{9.8}\times\dfrac{9.8}{20}$	M1	Need all terms. Condone sign errors and sin/cos confusion.
	$\dfrac{P}{12} + \dfrac{9000}{15} - R = 450$ $\left(\dfrac{P}{12} - R = -150\right)$	A1 A1	Substituted equation with at most one error. Any equivalent form. Correct substituted equation. Any equivalent form.
	Solve for P or R	DM1	Dependent on both preceding M marks
	$\left(\dfrac{2P}{12} = 750\right) \Rightarrow P = 4500$	A1	One correct
	$R = 525$ (530)	A1	Both correct
		(9)	
SC1	Misread mass = 9000kg Gives equations $\dfrac{P}{4} = R + 5880$ $\dfrac{P}{12} = R - 1470$ Solutions: $P = 44100$, $R = 5145$		B1 M1A0 M1A1ftA0 M1A1ftA1ft Total 7/9
SC2	Use of mass = weight = 9000 Gives equations $\dfrac{P}{4} = R + 600$ $\dfrac{P}{12} = R + 3810$ Solutions: $P = -19260$, $R = -5415$		B1 M1A1 M1A1A0 M1A0A0 Total 6/9
		[9]	

Question	Solution	Marks	Notes
3			
	Use of $F = \mu R$	B1	At least once
	Resolve horizontally	M1	Allow with their horizontal friction
	$S = \frac{4}{5}R \quad (S = F_A)$	A1	Correct unsimplified equation
	Resolve vertically	M1	Allow with their vertical friction
	$\frac{3}{5}S + R = 25g \quad F_B + R = 25g$ $\left(\frac{3}{5}S + \frac{5}{4}S = 25g, \quad S = \frac{500}{37}g\right)$	A1	Correct unsimplified equation
	Moments equation	M1	Any moments equation. Need all terms & dimensionally correct
	$\text{M}(A)\text{: } 25g \times 1.5\cos\theta = S \times 3\sin\theta + \frac{3}{5}S \times 3\cos\theta$ $\left(25g\cos\theta - \frac{6}{5}S\cos\theta = 2S\sin\theta\right)$ $\text{M}(B)\text{: } R \times 3\cos\theta = 25g \times 1.5\cos\theta + \frac{4}{5}R \times 3\sin\theta$	A1	Correct unsimplified equation
	M1A1 for first equation, M1A1 for second equation, M1A1 for third equation (i.e. mark in the order in which they appear rather than as listed on the mark scheme). If there are more than 3 equations, mark the 3 used or the best 3 if they go no further. Can also be solved using one resolution and two moments equations. Friction acting in the wrong direction scores A0.		
	$\tan\theta = \left(\frac{25g - \frac{6}{5}S}{2S}\right) = \left(\frac{25 - \frac{600}{37}}{\frac{1000}{37}}\right)$	DM1	Substitute to form equation in $\tan\theta$ only Condone in decimals Dependent on M marks for the equations
	$= \frac{325}{1000} \left(= \frac{13}{40}\right)$	A1	Or exact equivalent (0.325)
		(9)	
SC	It is possible to solve by resolving horizontally or vertically and taking moments about the centre: $1.5\cos\theta \times R = 1.5\cos\theta \times \frac{3}{5}S$ $+ 1.5\sin\theta \times S + 1.5\sin\theta \times \frac{4}{5}R$		M1A1 for a correct resolution M2A2 for a complete sets of equations to solve
		[9]	

Question Number	Solution	Marks	Notes
4a	<table><tr><td></td><td>$ABCD$</td><td>$PQRV$</td><td>$RSTU$</td><td>L</td></tr><tr><td>Mass ratio</td><td>64</td><td>4</td><td>16</td><td>44</td></tr><tr><td>c of m from AD</td><td>$4a$</td><td>$2a$</td><td>$5a$</td><td>(d)</td></tr></table>	B1 B1	Correct mass ratios for their split Correct distances from vertical axis for their split Must be multiples of a
	M(AD)	M1	Moments about AD or a parallel axis. Need all terms and dimensionally consistent.
	$64\times 4a-4\times 2a-16\times 5a=44d$	A1	Correct unsimplified equation Accept as part of a vector equation
	$\Rightarrow d=\frac{168}{44}a=\frac{42}{11}a$ *	A1*	Obtain **given answer** from correct working
		(5)	
4b	C of M of L lies at midpt of AC	B1	Seen or implied
	M(Mid pt AB)	M1	Use of moments to form equation in k.
	$\left(4-\frac{42}{11}\right)aM=4akM$	A1	Correct unsimplified equation. Allow with a not seen
	$k=\frac{1}{22}$	A1	0.05 or better (0.0454545…) Allow with a not seen
		(4)	
4b alt	C of M of L lies at midpt of AC	B1	Seen or implied by use of $\bar{x}=\bar{y}$ or $\tan 45°=1$
	Find $\bar{x}$ and $\bar{y}$ for system	M1	
	From AB: $\frac{42}{11}Ma+8akM=(1+k)M\bar{y}$ From BC: $\frac{46}{11}aM=(1+k)M\bar{x}$	A1	Correct unsimplified equations in $\bar{x}$ and $\bar{y}$ Allow with a not seen
	$\bar{x}=\bar{y}\Rightarrow\frac{42}{11}+8k=\frac{46}{11}\Rightarrow k=\frac{1}{22}$	A1	Allow with a not seen
4b alt	C of M of L lies at midpt of AC	B1	Seen or implied in moments equation
	If G is c of m of L then $\tan ABG=\frac{42}{46}$ and take moments about B	M1	Complete method for moments about B
	$8a\sin 45°\times kM$ $=\frac{Ma\sqrt{46^2+42^2}}{11}\sin(45°-ABG)$	A1	Correct unsimplified equation in k Allow with a not seen
	$\Rightarrow k=\frac{1}{22}$	A1	Allow with a not seen
4b alt	C of M of L lies at midpt of AC	B1	Seen or implied in moments equation

	Take moments about the centre of *ABCD*	M1	
	$M\times\dfrac{2\sqrt{2}}{11}a = kM\times4\sqrt{2}a$	A1	Correct unsimplified equation in k Allow with a not seen
	$\Rightarrow k=\dfrac{1}{22}$	A1	Allow with a not seen
		[9]	
Question Number	Solution	Marks	Notes
5a	$\mathbf{a}=\dfrac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$	M1	Differentiate to obtain **a** – powers going down
	$=(6t-9)\mathbf{i}+(2t+1)\mathbf{j}$	A1	differentiation correct
	$=9\mathbf{i}+7\mathbf{j}\ \ (\mathrm{m\ s^{-2}})$	A1	ISW if go on to find $\lvert\mathbf{a}\rvert$
		(3)	
5b	Instantaneous rest $\Rightarrow \mathbf{v}=0\mathbf{i}+0\mathbf{j}$ $\Rightarrow 3(t-1)(t-2)=0$ and $(t-2)(t+3)=0$	M1	Set $\mathbf{v}=0$ and solve for t (Need **both components** equal to zero)
	$\Rightarrow t=2$	A1	
	$\mathbf{r}=\int\mathbf{v}\mathrm{d}t$	M1	Integrate to obtain **r** – powers going up. Condone if no constant of integration seen.
	$=\left(t^3-\dfrac{9}{2}t^2+6t\right)\mathbf{i}+\left(\dfrac{1}{3}t^3+\dfrac{1}{2}t^2-6t\right)\mathbf{j}$	A1 A1	At most one error Correct integration Allow column vector. Allow A1A0 for correct integration and non-zero constants(s) of integration
	$=2\mathbf{i}-\dfrac{22}{3}\mathbf{j}$, distance $=\sqrt{2^2+\left(\dfrac{22}{3}\right)^2}$	DM1	Correct strategy to find the distance, i.e. substitute their value for t and use Pythagoras Dependent on the two preceding M marks
	$=\dfrac{2\sqrt{130}}{3}=7.60\ \ (\mathrm{m})$	A1	7.6 or better from correct work
		(7)	
		[10]	

Question Number	Solution	Marks	Notes
6a	$R = 6g\cos\alpha$	B1	Correct normal reaction
	Work done $= 15\times 0.25\times R$	M1	Correct method with their R
	$= 204\,(\text{J})$	A1	Or 200(J) Accept $21g$ or better. $(20.7692...g)$ Not $\dfrac{2646}{13}$
		(3)	
6b	NB The question specifies that the work-energy principle should be used, so solutions based on *suvat* equations are not accepted.		
	Initial KE – GPE lost – WD = final KE	M1	Use of work-energy to form equation in v. Dimensionally correct. Ignore sign errors. Allow WD or their WD
	$\frac{1}{2}\times 6\times 14^2 - 6g\times 15\times\frac{5}{13} - 6g\times 15\times\frac{3}{13}$ $= \frac{1}{2}\times 6v^2$ $\left(3\times 196 - \frac{450g}{13} - \frac{270g}{13} = 3v^2\right)$	A1ft A1ft	Unsimplified equation with at most one error Correct unsimplified equation Follow their WD
	$v = 3.88 \quad (3.9)$	A1	Max 3 sf
	Work-energy equation	M1	Complete method using work-energy to form equation in w. Dimensionally correct. Ignore sign errors.
	$\frac{1}{2}\times 6\times 14^2 - 6g\times 15\times\frac{3}{13} = \frac{1}{2}\times 6w^2$ or $\frac{1}{2}mw^2 = \frac{1}{2}mv^2 + mg\times\frac{15\times 5}{13}$	A1ft	Correct unsimplified equation Follow their WD or their v
	$w = 11.3 \quad (11)$	A1	Max 3 sf
		(7)	
		[10]	

Question Number	Solution	Marks	Notes
7			
7a	KE gain = final KE – initial KE	M1	KE equation for *B*. Allow for change in KE
	$\frac{48}{25}mu^2 = \frac{1}{2}mw^2 - \frac{1}{2}mu^2$	A1	Correct unsimplified equation to find w
	$\left(w^2 = \frac{121}{25}u^2, \quad w = \frac{11}{5}u\right)$		
	CLM: $3m \times 2u + mu = 3mv + mw$	M1	All terms required. Condone sign errors
	$\left(7mu = 3mv + \frac{11}{5}mu\right) \left(v = \frac{8}{5}u\right)$	A1	Correct unsimplified equation in v and w or their w
	Impact law:	M1	Used correctly
	$w - v = e(2u - u)$	A1	Correct unsimplified equation in v and w or their v and w
	Solve for e	DM1	Dependent on the preceding M marks
	$\frac{3}{5}u = eu, \quad e = \frac{3}{5}$	A1	
		(8)	
7b	Impact law: $fw=v$	M1	Condone sign error
	$f = \frac{8}{11}$	A1	0.73 or better Final answer must be positive
		(2)	
		[10]	

Question Number	Solution	Marks	Notes
8a	Horizontal component: $p = 8$	B1	
	Vertical component: $-12 = q - 3g$	M1	Complete method to find q using *suvat*. Condone sign errors.
	$q = 17.4$	A1	17 or better
	Speed $= \sqrt{8^2 + 17.4^2}$	M1	Use of Pythagoras to find speed using their velocity. Independent M mark
	$= 19.2 \quad (19)\left(\mathrm{m\,s^{-1}}\right)$	A1	3 sf or 2 sf
		(5)	
8b	Use of Pythagoras to find vertical component	M1	
	vertical component $= \pm 6$	A1	Seen or implied Accept without +/-
	$-6 = 6 - 9.8T$	DM1	Complete method using *suvat* to find required time Dependent on the previous M1
	$T = 1.22 \quad (1.2)$	A1	3 sf or 2 sf. Not $\frac{60}{49}$
		(4)	
8b alt	Use *suvat* and Pythagoras to form an equation in t	M1	Or an inequality
	$8^2 + (17.4 - gt)^2 = 100$	A1	Correct unsimplified equation for t Accept inequality
	Solve for T	DM1	Complete method to obtain T Dependent on the previous M1
	$T = 1.22 \quad (1.2)$	A1	3 sf or 2 sf. Not $\frac{60}{49}$
		(4)	
8c	Velocity perpendicular $\Rightarrow$ vertical component $= \frac{2}{3} \times 8$	M1	Complete method to find vertical component of velocity at B
	$= \frac{16}{3}$	A1	
	$(-12)^2 = \left(\frac{16}{3}\right)^2 - 2g(-h)$	DM1	Complete method to find the required vertical distance using their vertical component of the velocity Dependent on the previous M1
	$h = 5.90 \quad (5.9)\,(\mathrm{m})$	A1	Max 3 sf
		(4)	
8c alt	$\begin{pmatrix} 8 \\ 17.4 - gt \end{pmatrix} \cdot \begin{pmatrix} 8 \\ -12 \end{pmatrix} = 0$ and time $= 3 - t$	M1	Complete method to find the time from B to A
	Time $= 3 - 1.23... = 1.768...$	A1	
	$s = vt - \frac{1}{2}gt^2 = 12t - 4.9t^2$	DM1	Complete method to find the required vertical distance using their time Dependent on the previous M1
	$s = 5.9$ (m)	A1	Max 3 sf

		[13]	

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