Mark Scheme (Results)

October 2020

Pearson Edexcel International Advanced Level In Mechanics M3 (WME03/01)

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 2020
Publications Code WME03_01_2006_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 $\surd$ 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)
   - d… or dep – dependent
   - indep – independent
   - dp decimal places
   - sf significant figures
   - $*$ The answer is printed on the paper or ag- answer given
   - $\sqsubset$ 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	Scheme	Marks
1	$\omega = \dfrac{2\pi}{0.5}\left(= 4\pi\right)$	B1
	$R = m\omega^2 \times 0.35 \quad \left(= \dfrac{28m\pi^2}{5}\right)$	M1
	$F_r = mg$	B1
	$F_r \leq \mu R$	M1
	$mg \leq \mu \dfrac{28m\pi^2}{5}$	DM1
	$\mu \geq 0.18 \quad \left(\mu \geq 0.177\right)$	A1
		[6]

B1 Use of period to find ω.

M1 Equation of motion horizontally. Must be considering *R*. Acceleration can be in either circular motion form.

B1 Resolve vertically. If only seen within friction inequality, then must be correct way round.

M1 Use of $F_r \leq \mu R$. Condone use of strict inequality for this mark.

D**M1** Substitute in F_r and R. Could be an equation. Dependent on first M mark.

A1 $\mu \geq 0.18 \quad \left(\mu \geq 0.177\right)$ **cao**

Note: If equation used throughout and correct inequality added for final answer, full marks are available if no incorrect working seen.

Question Number	Scheme	Marks
2(a)	$\cos\theta = \frac{4}{5}$	B1
	$2T\cos\theta = 12$	M1A1
	$2T\left(\frac{4}{5}\right) = 12 \Rightarrow T = \frac{60}{8} = 7.5\,(\text{N})$	A1
		(4)
(b)	$\text{Ext} = 2(2.5) - 3 = 2\,\text{m}$	
	$7.5 = \frac{\lambda \times 2}{3} \Rightarrow \lambda = 11.25\,(\text{N})$ *	M1A1*
		(2)
(c)	$\text{EPE} = \frac{11.25 \times 2^2}{2 \times 3} = 7.5\,(\text{J})$	M1A1
		(2)
		[8]

(a)

B1 $\cos\theta = \frac{4}{5}$ seen or implied.

M1 Resolving vertically, with 2 equal tensions (implied) and weight.

A1 Correct equation.

A1 $T = \frac{15}{2} = 7.5\ \text{N}$ accept any equivalent fraction, since *g* not used.

(b)

M1 Use of Hooke's Law with their tension to form equation in λ. Must be using natural length of 3 (or 1.5 for half string), but condone incorrect extension for M mark.

A1* 11.25 or any equivalent fraction.

(c)

M1 Attempt at EPE in equilibrium position. Must have same extension as (b). Condone missing half in EPE formula. If using half strings, then they must include the EPE of both strings. Must be using natural length of 3 (or 1.5 for half string). Allow if an embedded term in an energy equation.

A1 7.5 J. Accept any equivalent. Must be a clear answer (not embedded).

Question Number	Scheme	Marks
3	$\Delta\text{GPE} = 2g \times 0.7 \sin 30 \left(= 6.86\right)$	B1
	For a correct EPE term	B1
	$WD = 2g \cos 30 \times 0.3 \times 0.7 \left(= 3.56\right)$	M1A1
	$\frac{12\left(0.5\right)^2}{2 \times 0.8} + 6.86 = \frac{12\left(0.2\right)^2}{2 \times 0.8} + 0.7 \times 5.09 + \frac{1}{2} \times 2v^2$	M1A1
	$v^2 = 4.87 \Rightarrow v = 2.21 \left(\text{ms}^{-1}\right) \quad (2.2)$	A1
		[7]

B1 Correct unsimplified change in GPE.

B1 For a correct EPE term $\frac{12\left(0.5\right)^2}{2 \times 0.8}$ **or** $\frac{12\left(0.2\right)^2}{2 \times 0.8}$

M1 Complete method to find Work Done.

A1 Correct unsimplified expression for Work Done.

M1 Forming an energy equation. Must have 2 EPE terms, change in GPE, WD and KE. Must be dimensionally correct, but follow through their GPE and WD and condone missing half in EPE terms.

A1 Fully correct (unsimplified) equation.

A1 2.21 or 2.2 **cao**

Note: answers using constant acceleration score no marks.

Question Number	Scheme	Marks
4(a)	$M\bar{y} = (\rho)\pi\int_0^a y\left(a^2 - y^2\right)\mathrm{d}y$	M1 A1
	$M\bar{y} = (\rho)\pi\left[\frac{a^2y^2}{2} - \frac{y^4}{4}\right]_0^a$	A1
	$\left(M\bar{y} = (\rho)\pi\frac{a^4}{4}\right)$	
	$\bar{y} = \frac{(\pi\rho)\frac{a^4}{4}}{(\pi\rho)\frac{2a^3}{3}} = \frac{3a}{8}$ *	M1A1 *
	S.C. Clear use of r = 1, with a substituted at end can score max M1A0A0 M1A0	(5)
(b)	$(k+1)m\bar{x} = kma\left(\Rightarrow \bar{x} = \frac{ka}{k+1}\right)$	M1A1
	$(k+1)m\bar{y} = m\times\frac{3}{8}a\left(\Rightarrow \bar{y} = \frac{3a}{8(k+1)}\right)$	A1
	$\tan\alpha = \frac{\bar{x}}{\bar{y}}$	M1
	$k = \frac{3\sqrt{3}}{8}$	A1
		(5)
		[10]
Alt b	Moments about O $m\times\frac{3a}{8}\sin\alpha = kma\times\cos\alpha$	M1A2
	$k = \frac{3\sqrt{3}}{8}$	M1A1

(a)

M1 Using $(\pi)\int_0^r x^2 y\,\mathrm{d}y$ with or without π. Must be dimensionally correct with integrand of the form $y\left(a^2-y^2\right)$. Limits not needed.

A1 $\int_0^a y\left(a^2-y^2\right)\mathrm{d}x$ Correct integral. Limits not needed.

A1 Correct integration. Limits not needed.

M1 Using $\bar{y}=\dfrac{\int_0^a \pi x^2 y\,\mathrm{d}y}{\frac{2}{3}\pi a^3}$. π in numerator and denominator or in neither.

A1 Correct **given** result with no errors seen. **Cso**

S.C. If they clearly find CoM of a hemisphere with a radius other than *a*, they can gain the M marks for a correct method for their hemisphere. If they work with an algebraic radius, they can gain the first 2 A marks and if they replace their radius with *a* at the end, they can gain the final mark.

(b) First 3 marks can be awarded for equations only seen as part of a vector equation.

M1 Dimensionally correct moments equation for $\bar{x}$ or $\bar{y}$

A1 Correct equation in $\bar{x}$ or $\bar{y}$ (Give BOD on use of *x* and/or *y*).

A1 Correct equations for $\bar{x}$ and $\bar{y}$

M1 Dividing to form equation in $\tan\alpha$ and solve for *k*. Trig must be right

A1 $k=\dfrac{3\sqrt{3}}{8}$ any correct exact form.

ALT b) - Taking moments about *O*.

M1 Dimensionally correct moments equation about *O*.

A1 Moments equation with at most one error.

A1 Fully correct equation.

M1 Solve for *k*.

A1 c.a.o.

Question Number	Scheme	Marks
5(a)	$0.5v\dfrac{\mathrm{d}v}{\mathrm{d}x}=-\dfrac{2}{x^3}$	M1
	$\int v\,\mathrm{d}v=\int -\dfrac{4}{x^3}\,\mathrm{d}x$	
	$\dfrac{v^2}{2}=\dfrac{2}{x^2}\quad(+k)$	DM1A1
	$v^2=\dfrac{4}{x^2}+2k$	
	$v=3, x=1\Rightarrow 2k=5$	DM1
	$v^2=\dfrac{4}{x^2}+5$ *	A1 *
		(5)
	Alt for first 2 marks using Energy	
	Use of $W=\int F dx$	M1
	Attempt integration **and** equate to change in KE.	M1
(b)	$\dfrac{\mathrm{d}x}{\mathrm{d}t}=\sqrt{\dfrac{4}{x^2}+5}$	M1
	$\int \dfrac{x}{\sqrt{5x^2+4}}\mathrm{d}x=\int \mathrm{d}t$	M1A1
	$\dfrac{1}{5}\sqrt{5x^2+4}=t\qquad(+k_1)$	DM1A1
	$x=1,\ t=1\Rightarrow k_1=-\dfrac{2}{5}$	DM1
	$t=\dfrac{2+\sqrt{5x^2+4}}{5}$	A1
		(7)

(a)

M1 Dimensionally correct equation of motion. Acceleration must be in form $v\frac{\mathrm{d}v}{\mathrm{d}x}$. Condone missing minus sign.

DM1 Separate variables **and** attempt integration. Condone missing minus sign.

A1 Correct integrals. Condone missing constant.

DM1 Use $v = 3, x = 1$ to find constant of integration. Dependent on both previous M marks.

A1* Reach given result with no errors.

Alt – Definite Integration/Energy Work.

M1 – Equate change in KE to Integral for WD. Integration not needed for this mark and condone inconsistent signs.

$$\frac{1}{2}\times 2v^2 - \frac{1}{2}\times 2\times 3^2 = \int (\pm)\frac{2}{x^3}dx$$

DM1 Attempt integration. Condone inconsistent signs.

A1 Correct integration, with consistent signs for KE and WD.

DM1 Substitute in limits.

A1 Reach given result with no errors.

(b)

M1 Use $v = \frac{\mathrm{d}x}{\mathrm{d}t}$ to form differential equation in x and t.

M1 Separate variables and to produce functions ready to be integrated.

A1 Correct integrands, written in a form that can be integrated.

DM1 Valid attempt to integrate their expression. If they have an incorrect expression, the integration must not be significantly simplified. Dependent on first 2 M marks.

A1 Correct integration. Condone missing constant.

DM1 Use $x = 1, t = 1$ to find constant of integration. Dependent on all 3 M marks.

A1 Correct result. (cso)

Question Number	Scheme	Marks
6(a)	$\dfrac{\frac{3}{4}mge}{a} = mg$	M1
	$e = \dfrac{4}{3}a \Rightarrow AP = \dfrac{7}{3}a$	A1
		(2)
(b)	$m\ddot{x} = mg - \dfrac{\frac{3}{4}mg\left(x + \frac{4}{3}a\right)}{a}$	M1A1
	$m\ddot{x} = mg - \dfrac{3mgx}{4a} - mg = -\dfrac{3mgx}{4a}$	
	$\ddot{x} = -\dfrac{3g}{4a}x = -\omega^2 x \therefore \text{SHM}$	DM1A1
	$\text{amp} = \dfrac{2}{3}a \qquad \text{KE} = -\dfrac{mg}{2}$	B1
	$\dfrac{2}{3}a < \dfrac{4}{3}a$ oe So string remains taut or String never goes slack, therefore always SHM	B1
		(6)
(c)	$v^2 = \dfrac{3g}{4a}\left(\left(\dfrac{2a}{3}\right)^2 - \left(\dfrac{a}{3}\right)^2\right)$	M1A1ft
	$v^2 = \dfrac{ag}{4} \qquad v = \dfrac{\sqrt{ag}}{2}$	A1
		(3)
Alt	$\text{Energy}\dfrac{\frac{3mg}{4}(2a)^2}{2a} = \dfrac{\frac{3mg}{4}(a)^2}{2a} + mga + \dfrac{1}{2}mv^2$	M1A1
	$v = \dfrac{\sqrt{ag}}{2}$	A1
(d)	$-\dfrac{a}{3} = \dfrac{2a}{3}\cos(\omega t) \qquad \left[\dfrac{a}{3} = \dfrac{2a}{3}\sin(\omega t) \qquad \dfrac{T}{4} = \pi\sqrt{\dfrac{a}{3g}}\right]$	M1A1ft
	$\cos(\omega t) = -\dfrac{1}{2}$	

Question Number	Scheme	Marks
	$t\sqrt{\frac{3g}{4a}}=\frac{2\pi}{3}$	
	$t=\frac{2\pi}{3}\sqrt{\frac{4a}{3g}}$	DM1A1
		(4)
		[14]

(a) **M1** Resolve vertically. Can be in either *e* or *AP*.

A1 $AP=\frac{7}{3}a$

(b) **M1** Form an equation of motion including weight and tension. Variable must be measured from equilibrium position. If *e* is used, this must have been defined already in working (part (a)). Acceleration can be $\ddot{x}$ or *a*.

A1 Correct unsimplified equation. Can use $\ddot{x}$ or *a*, but if *a* used, it must be in same direction as *x*.

DM1 Solve to obtain $\ddot{x}=$ Must be $\ddot{x}$ now.

A1 $\ddot{x}=-\frac{3g}{4a}x=-\omega^2 x\therefore \text{SHM}$ Correct equation **and** statement.

B1M1 Correct/sufficient values found to establish string remains taut.

B1A1 Appropriate argument

(c) **M1** Use of $v^2=\omega^2\left(a^2-x^2\right)$ with their ω (ignore the dimensions of their ω)

A1ft Correct equation in *v* and *a*. ft their ω and amplitude(really their AP. Condone failing to add *a* to their extension in (a))

A1 Correct *v*. c.s.o., but award if correct ω found with only sign error in (b)

Alt for first 2 Marks

M1 Energy equation. Must contain 2 EPE terms, GPE and KE.

A1 Correct equation.

(d) **M1** Use of $x="a"\cos\left(\omega t\right)$ or $x="a"\sin\left(\omega t\right)$. Amplitude must be consistent with their *AP*.

A1 Correct equation in ω

DM1 Solve equation to find expression for *t*. Must now have a full method to find complete time.

A1 Any correct equivalent. Must come from correct working throughout, but condone sign error on acceleration in (b).

Question Number	Scheme	Marks
7(a)	$\frac{1}{2}m(8ag)+mg(8a)=\frac{1}{2}mv^2+mg(8a\cos\theta)$	M1A1A1
	$\left(v^2=24ga-16ga\cos\theta\right)$	
	$T+mg\cos\theta=\frac{mv^2}{8a}$	M1A1
	$T+mg\cos\theta=\frac{m\left(24ga-16ga\cos\theta\right)}{8a}$	DM1
	$T+mg\cos\theta=3mg-2mg\cos\theta$	
	$T=3mg-3mg\cos\theta=3mg(1-\cos\theta)$ *	A1*
		(7)
(b)	At B $v_B{}^2=24ga$	B1
	$T_1=\frac{m(24ag)}{8a}=3mg$ or $T_2=\frac{m(24ag)}{3a}=8mg$	B1
	$\Delta T=5mg$	B1
		(3)
(c)	$\frac{1}{2}mv_1{}^2=\frac{1}{2}m(8ag)+mg(11a)$	M1
	$v_1{}^2=30ag$	
	After impact $v_2{}^2=20ag$	A1
	$\frac{1}{2}m(20ag)-mg(3a)=\frac{1}{2}mv_2{}^2+mg(8a\cos\alpha)$	M1A1
	$\left(v_2{}^2=14ga-16ga\cos\alpha\right)$	
	$mg\cos\alpha=\frac{m\left(14ga-16ga\cos\alpha\right)}{8a}$	M1A1
	$mg\cos\alpha=\frac{7mg}{4}-2mg\cos\alpha$	
	$\cos\alpha=\frac{7}{12}$ *	A1*

Question Number	Scheme	Marks
		(7)
		[17]

(a)

M1 Attempt at energy equation at a general point. Must be dimensionally correct and contain two KE terms and a change in GPE.

A1, A1 Correct unsimplified equation. -1 each error.

M1 Attempt to resolve radially. Acceleration can be in either circular form.

A1 Correct equation. Must be $\frac{mv^2}{r}$

DM1 Eliminate v to produce equation in T, m, g, θ. Dependent of the previous 2 M marks.

A1* Reach given result with no errors seen.

(b)

B1 $v_B^{\,2} = 24ga$. Correct expression for speed (or speed squared) at B. This mark will **not** be implied by a correct tension if they simply use the final result in (a).

B1 Correct expression for Tension at B, for either radius. Can be found using the result from (a).

B1 Correct expression for change in tension.

(c)

M1 Attempt at energy equation at wall. Must include 2 KE terms and a change in GPE.

A1 Correct speed (or speed squared, or KE) after impact.

M1 Attempt at Energy equation to α. Must include 2 KE terms and a change in GPE.

A1 Correct energy equation.

M1 Attempt at radial equation. If T included, it must be set to zero before this mark is awarded. Condone use of $3a$ for this mark?

A1 Correct equation in $\cos\alpha$ only oe.

A1* Solve to reach given result.

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