Pearson Edexcel

Mark Scheme (Results)

October 2020

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

Question Number	Scheme	Marks
1	$\omega = \frac{2\pi}{0.5}\left(= 4\pi\right)$	B1
	$R = m\omega^2 \times 0.35 \quad \left(= \frac{28m\pi^2}{5}\right)$	M1
	$F_r = mg$	B1
	$F_r \le \mu R$	M1
	$mg \le \mu \frac{28m\pi^2}{5}$	DM1
	$\mu \ge 0.18 \quad \left(\mu \ge 0.177\right)$	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 $F_r \le \mu R$. 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 $\mu \ge 0.18 \quad \left(\mu \ge 0.177\right)$ **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)	$\text{Ext} = 2(2.5) - 3 = 2\text{ m}$	
	$7.5 = \frac{\lambda \times 2}{3} \Rightarrow \lambda = 11.25$ (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	$\Delta\text{GPE} = 2g \times 0.7\sin 30 (= 6.86)$	B1
	For a correct EPE term	B1
	$WD = 2g\cos 30 \times 0.3 \times 0.7 (= 3.56)$	M1A1
	$\frac{12(0.5)^2}{2\times 0.8} + 6.86 = \frac{12(0.2)^2}{2\times 0.8} + 0.7\times 5.09 + \frac{1}{2}\times 2v^2$	M1A1
	$v^2 = 4.87 \Rightarrow v = 2.21(\text{ms}^{-1}) \quad (2.2)$	A1
		[7]

B1 Correct unsimplified change in GPE.

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

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

A1 $\int_0^a y\left(a^2 - y^2\right) dx$ Correct integral. Limits not needed.

A1 Correct integration. Limits not needed.

M1 Using $\bar{y} = \dfrac{\int_0^a \pi x^2 y \, dy}{\frac{2}{3}\pi a^3}$. 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)	$0.5v\dfrac{dv}{dx} = -\dfrac{2}{x^3}$	M1
	$\int v\, dv = \int -\dfrac{4}{x^3}\, dx$	
	$\dfrac{v^2}{2} = \dfrac{2}{x^2} \quad (+k)$	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)	$\dfrac{dx}{dt} = \sqrt{\dfrac{4}{x^2} + 5}$	M1
	$\int \dfrac{x}{\sqrt{5x^2+4}} dx = \int dt$	M1A1
	$\dfrac{1}{5}\sqrt{5x^2+4} = t \quad (+k_1)$	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.

<u>Alt – Definite Integration/Energy Work.</u>

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
	$e = \frac{4}{3}a \Rightarrow AP = \frac{7}{3}a$	A1
		(2)
(b)	$m\ddot{x} = mg - \dfrac{\frac{3}{4}mg\left(x + \frac{4}{3}a\right)}{a}$	M1A1
	$m\ddot{x} = mg - \dfrac{3mgx}{4a} - mg = -\dfrac{3mgx}{4a}$	
	$\ddot{x} = -\dfrac{3g}{4a}x = -\omega^2 x \therefore$ SHM	DM1A1
	amp $= \frac{2}{3}a$ KE $= -\dfrac{mg}{2}$	B1
	$\frac{2}{3}a < \frac{4}{3}a$ 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
	$v^2 = \dfrac{ag}{4}$ $v = \dfrac{\sqrt{ag}}{2}$	A1
		(3)
Alt	Energy $\dfrac{\frac{3mg}{4}(2a)^2}{2a} = \dfrac{\frac{3mg}{4}(a)^2}{2a} + mga + \frac{1}{2}mv^2$	M1A1
	$v = \dfrac{\sqrt{ag}}{2}$	A1
(d)	$-\dfrac{a}{3} = \dfrac{2a}{3}\cos(\omega t)$ $\left[\dfrac{a}{3} = \dfrac{2a}{3}\sin(\omega t) \quad \dfrac{T}{4} = \pi\sqrt{\dfrac{a}{3g}}\right]$	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 $x=\text{"}a\text{"}\cos\left(\omega t\right)$ or $x=\text{"}a\text{"}\sin\left(\omega t\right)$. 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.