GCE A level Mathematics (9MA0) – Shadow Paper (Set 1)
9MA32-01 AL Mechanics

October 2021 Shadow Paper mark scheme

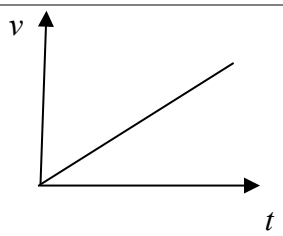
Please note that this mark scheme is not the one used by examiners for making scripts. It is intended more as a guide, indicating where marks are given for correct answers. As such, it may not show follow-through marks (marks that are awarded despite errors being made) or special cases.

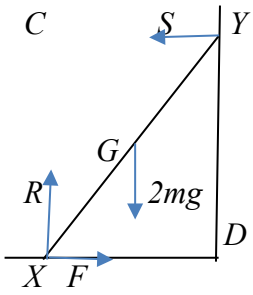
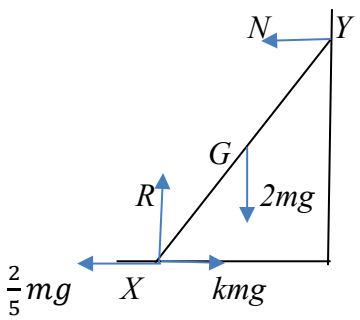
It should also be noted that for many questions, there may be alternative methods of finding correct solutions that are not shown here – they will be covered in the formal mark scheme from the original paper.

This document is intended for guidance only and may differ significantly from the examiners' final mark scheme for the original paper which was published in December 2020.

Guidance on the use of codes within this document
M1 – method mark. This mark is generally given for an appropriate method in the context of the question. This mark is given for showing your working and may be awarded even if working is incorrect. A1 – accuracy mark. This mark is generally given for a correct answer following correct working. B1 – working mark. This mark is usually given when working and the answer cannot easily be separated. Some questions require all working to be shown; in such questions, no marks will be given for an answer with no working (even if it is a correct answer).

Question	Scheme	Marks	AOs
1(a)	Use of $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ with $t = 4$: $\mathbf{v} = 6\mathbf{j} + 4(3\boldsymbol{i} - 2\boldsymbol{j})$ **OR integration**: $\boldsymbol{v} = (3\boldsymbol{i} - 2\boldsymbol{j})t + 6\mathbf{j}$, with $t = 4$	M1	3.1a
	$\boldsymbol{v} = 12\boldsymbol{i} - 2\boldsymbol{j}$	A1	1.1b
		(2)	
1(b)	Use of $\boldsymbol{r} = \boldsymbol{u}t + \frac{1}{2}\boldsymbol{a}t^2$ at $t = 5$: $(2\boldsymbol{i} - 8\boldsymbol{j}) + \left[5 \times 6\boldsymbol{j} + \frac{1}{2} \times (3\boldsymbol{i} - 2\boldsymbol{j}) \times 5^2\right]$ **OR**: find **v** at $t = 5$: $6\boldsymbol{j} + 5(3\boldsymbol{i} - 2\boldsymbol{j}) = (15\boldsymbol{i} - 4\boldsymbol{j})$ then use $\boldsymbol{r} = \frac{1}{2}(\boldsymbol{u} + \boldsymbol{v})t$ $(2\boldsymbol{i} - 8\boldsymbol{j}) + \left[\frac{1}{2}[6\boldsymbol{j} + (15\boldsymbol{i} - 4\boldsymbol{j})] \times 5\right]$ or $\boldsymbol{r} = \boldsymbol{v}t - \frac{1}{2}\boldsymbol{a}t^2$ $(2\boldsymbol{i} - 8\boldsymbol{j}) + \left[5 \times (15\boldsymbol{i} - 4\boldsymbol{j}) - \frac{1}{2} \times (3\boldsymbol{i} - 2\boldsymbol{j}) \times 5^2\right]$ **OR integration:** $\boldsymbol{r} = (2\boldsymbol{i} - 8\boldsymbol{j}) + \left[(3\boldsymbol{i} - 2\boldsymbol{j})\frac{1}{2}t^2 + 6t\boldsymbol{i}\right]$, with $t = 5$	M1	3.1a
	$\boldsymbol{r} = 39.5\boldsymbol{i} - 3\boldsymbol{j}$	A1	2.2a
		(2)	
			(4 marks)

Question	Scheme	Marks	AOs
	Mark parts (a) and (b) together		
2(a)	Equation of motion for A	M1	3.3
	$8mg\ sin\,\alpha - F - T = 8ma$	A1	1.1b
		(2)	
2(b)	Resolve perpendicular to the plane	M1	3.4
	$R = 8mg\ cos\,\alpha$	A1	1.1b
	$F = \frac{1}{8}R$	B1	1.2
	Equation of motion for B **OR** for whole system	M1	3.3
	$T - 2mg = 2ma$ **OR** $8mg\ sin\,\alpha - F - 2mg = 8ma + 2ma$	A1	1.1b
	Complete method to solve for a	DM1	3.1b
	$a = \frac{1}{65}g$ *	A1*	2.2a
		(7)	
2(c)		B1	1.1b
	e.g. acceleration (of B) is constant; dependent on first B1	DB1	2.4
		(2)	
2(d)	Mass of the string OR Pulley may not be smooth OR Pulley may not be light OR Masses may not be particles OR String may not be light OR String may not be inextensible.	B1	3.5a
		(1)	
			(12 marks)
Notes:			

Question	Scheme	Marks	AOs
	Part (a) is a 'Show that..' so equations need to be given in full to earn A marks		
3(a)			
	Moments equation: (M1A0 for a moments inequality)	M1	3.3
	M(X), $6mga\cos\theta = 6Sa\sin\theta$ M(Y), $2mg3a\cos\theta + 6Fa\sin\theta = 6Ra\cos\theta$ M(C), $F \times 6a\sin\theta = 2mga\cos\theta$ M(D), $6Ra\cos\theta = 2mga\cos\theta + 6Sa\sin\theta$ M(G), $3Ra\cos\theta = 3Fa\sin\theta + 3Sa\sin\theta$.	A1	1.1b
	(↕) $R = mg$ **OR** (↔) $F = S$	B1	3.4
	Use their equations (they must have enough) and $F \leq \mu R$ to give an inequality in μ and θ **only** (allow DM1 for use of $F = \mu R$ to give an *equation* in μ and θ only)	DM1	2.1
	$\mu \geq \frac{1}{2}\cot\theta$*	A1*	2.2a
		(5)	
3(b)			
	Moments equation:	M1	3.4
	M(X), $6mga\cos\theta = 6Na\sin\theta$	A1	1.1b

	$N = kmg - F$ **OR** $R = 2mg$	B1	3.3
	Use their equations (they must have enough) to solve for k (numerical)	DM1	3.1b
	$k = 0.73$	A1	1.1b
		(5)	
			(10 marks)

Notes:

3a	M1	
	A1	
	B1	
	DM1	
	A1*	
3b	M1	
	A1	
	B1	
	DM1	
	A1	

Question	Scheme	Marks	AOs
	Note that $g = 10$; penalise once for whole question if $g = 9.8$		
4(a)	Use $s = ut + \frac{1}{2}at^2$ vertically or any complete method to give an equation in t only	M1	3.4
	$-35 = 30\sin\alpha \times t - \frac{1}{2} \times g \times t^2$	A1	1.1b
		M (A)1	1.1b
	$t = 5$ (s)	A1	1.1b
		(4)	
4(b)	Horizontal velocity component at $A = 30\cos\alpha$ (24)	B1	3.4
	Complete method to find vertical velocity component at A	M1	3.4
	$30\sin\alpha - g \times 5$ **OR** $\sqrt{(-18)^2 + 2g \times 35}$ (32)	A1**ft**	1.1b
	Sub for trig and square, add and square root : $\sqrt{24^2 + (-32)^2}$	M1	3.1b
	40 (m s^{-1})	A1	1.1b
		(5)	
4(c)	e.g. the dimensions of the stone could affect its motion, spin of the stone, wind effect, shape of the stone	B1	3.5b
		(1)	
			(10 marks)

Notes:		
4a		
4b		

4c		

Question	Scheme	Marks	AOs
	Allow column vectors throughout this question		
5(a)	Differentiate **v** wrt t	M1	3.1a
	$4\boldsymbol{i} + 3t^{-\frac{1}{2}}\mathbf{j}$ isw	A1	1.1b
		(2)	
5(b)	$2 \times 4t = 6t^{1/2}$	M1	2.1
	Solve for t	DM1	1.1b
	$t = \frac{9}{16}$	A1	1.1b
		(3)	
5(c)	Integrate **v** wrt t	M1	3.1a
	$\boldsymbol{r} = 2t^2\boldsymbol{i} + 4t^{\frac{3}{2}}\boldsymbol{j}\ (+\boldsymbol{C})$	A1	1.1b
	$t = 9$, $\mathbf{r} = 162\boldsymbol{i}$ => $\mathbf{C} = -108\boldsymbol{j}$ so $\boldsymbol{r} = 2t^2\boldsymbol{i} + 4t^{\frac{3}{2}}\boldsymbol{j} - 108\boldsymbol{j}$	A1	2.2a
		(3)	
5(d)	$\sqrt{(4t)^2 + (6t^{\frac{1}{2}})^2} = 20$ or $(4t)^2 + (6t^{\frac{1}{2}})^2 = 20^2$	M1	2.1
	$16t^2 + 36 = 400$	M(A)1	1.1b
	$t = 4$	A1	1.1b
	$\boldsymbol{r} = 32\boldsymbol{i} - 76\boldsymbol{j}$	M1	1.1b
	$\sqrt{32^2 + (-76)^2}$	M1	3.1a
	$\sqrt{6800}$ $(20\sqrt{17})$ (m)	A1	1.1b
		(6)	
			(14 marks)
Notes:			
5a	M1		

	A1	
5b	M1	
	DM1	
	A1	
5c	M1	
	A1	
	A1	
5d	M1	
	M(A)1	
	A1	
	M1	
	M1	
	A1	