



**ADVANCED  
General Certificate of Education  
2015**

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**Mathematics**  
**Assessment Unit M2**  
*assessing*  
**Module M2: Mechanics 2**

**[AMM21]**

**MONDAY 22 JUNE, AFTERNOON**

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**MARK  
SCHEME**

## GCE Advanced/Advanced Subsidiary (AS) Mathematics

### Mark Schemes

#### Introduction

The mark scheme normally provides the most popular solution to each question. Other solutions given by candidates are evaluated and credit given as appropriate; these alternative methods are not usually illustrated in the published mark scheme.

The marks awarded for each question are shown in the right-hand column and they are prefixed by the letters **M**, **W** and **MW** as appropriate. The key to the mark scheme is given below:

**M** indicates marks for correct method.

**W** indicates marks for correct working.

**MW** indicates marks for combined method and working.

The solution to a question gains marks for correct method and marks for an accurate working based on this method. Where the method is not correct no marks can be given.

A later part of a question may require a candidate to use an answer obtained from an earlier part of the same question. A candidate who gets the wrong answer to the earlier part and goes on to the later part is naturally unaware that the wrong data is being used and is actually undertaking the solution of a parallel problem from the point at which the error occurred. If such a candidate continues to apply correct method, then the candidate's individual working must be followed through from the error. If no further errors are made, then the candidate is penalised only for the initial error. Solutions containing two or more working or transcription errors are treated in the same way. This process is usually referred to as "follow-through marking" and allows a candidate to gain credit for that part of a solution which follows a working or transcription error.

#### Positive marking:

It is our intention to reward candidates for any demonstration of relevant knowledge, skills or understanding. For this reason we adopt a policy of **following through** their answers, that is, having penalised a candidate for an error, we mark the succeeding parts of the question using the candidate's value or answers and award marks accordingly.

Some common examples of this occur in the following cases:

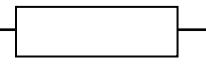
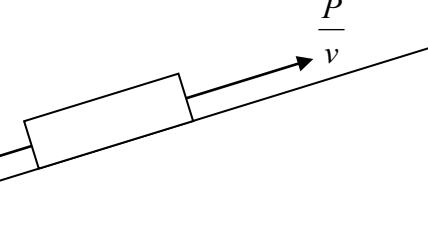
- (a) a numerical error in one entry in a table of values might lead to several answers being incorrect, but these might not be essentially separate errors;
- (b) readings taken from candidates' inaccurate graphs may not agree with the answers expected but might be consistent with the graphs drawn.

When the candidate misreads a question in such a way as to make the question easier only a proportion of the marks will be available (based on the professional judgement of the examining team).

		AVAILABLE MARKS
1	(i) initial position $\Rightarrow t = 0$	
	$\mathbf{s} = 2\mathbf{i} - \mathbf{j}$	M1
	no $\mathbf{k}$ vector $\therefore$ on $\mathbf{i}-\mathbf{j}$ plane	W1
(ii)	$\mathbf{v} = \frac{d\mathbf{s}}{dt}$	M1
	$\mathbf{v} = (2t)\mathbf{i} + (3t^2)\mathbf{j} + (2t + 2)\mathbf{k}$	W1
	at $t = 2$ , $\mathbf{v} = 4\mathbf{i} + 12\mathbf{j} + 6\mathbf{k}$	MW1
	speed = $\sqrt{4^2 + 12^2 + 6^2}$	
	speed = $14 \text{ ms}^{-1}$	MW1
(iii)	$\mathbf{a} = \frac{d\mathbf{v}}{dt}$	M1
	$\mathbf{a} = 2\mathbf{i} + 6t\mathbf{j} + 2\mathbf{k}$	W1
	at $2\mathbf{i} + 8\mathbf{j} + 2\mathbf{k}$ ,	
	$6t = 8$	
	$t = \frac{4}{3}$	MW1
		9

		AVAILABLE MARKS
2	(i) unit vector in the direction of $\mathbf{F}_1$ is $\frac{1}{9} \begin{pmatrix} 4 \\ -4 \\ -7 \end{pmatrix}$	M1
	$\mathbf{F}_1$ is then $2 \begin{pmatrix} 4 \\ -4 \\ -7 \end{pmatrix}$	W1
	unit vector in the direction of $\mathbf{F}_2$ is $\frac{1}{3} \begin{pmatrix} 2 \\ 1 \\ -2 \end{pmatrix}$	
	$\mathbf{F}_2$ is then $2 \begin{pmatrix} 2 \\ 1 \\ -2 \end{pmatrix}$	MW1
	Resultant is $\mathbf{F}_1 + \mathbf{F}_2 = \begin{pmatrix} 12 \\ -6 \\ -18 \end{pmatrix}$	MW1
	(ii) Using $\mathbf{F} = m\mathbf{a}$	M1
	$\begin{pmatrix} 12 \\ -6 \\ -18 \end{pmatrix} = 3\mathbf{a}$	
	$\mathbf{a} = \begin{pmatrix} 4 \\ -2 \\ -6 \end{pmatrix}$	W1
	(iii) $\mathbf{v} = \mathbf{u} + \mathbf{a}t$	M1
	$\mathbf{v} = \begin{pmatrix} -1 \\ 3 \\ 6 \end{pmatrix} + \begin{pmatrix} 4 \\ -2 \\ -6 \end{pmatrix}$	
	at $t = 1$ , $\mathbf{v} = \begin{pmatrix} 3 \\ 1 \\ 0 \end{pmatrix}$	MW1
	(iv) scalar product $\begin{pmatrix} -1 \\ 3 \\ 6 \end{pmatrix} \cdot \begin{pmatrix} 3 \\ 1 \\ 0 \end{pmatrix} = (-1)(3) + (3)(1) + (6)(0) = 0$	M1
	$\therefore$ perpendicular to original direction	MW1
		10

		AVAILABLE MARKS
3	(i) K.E. = $\frac{1}{2} mv^2$	M1
	Change in K.E. = $\frac{1}{2} (75)7^2 - \frac{1}{2} (75)4^2$	
	Change = 1237.5 J loss	W1
(ii)	Work done = Force × Distance	M1
	Work done = $14 \times 2100$	
	= 29 400 J	W1
(iii)	Loss of P.E. = $mgh$	M1
	= $75 (9.8)(60 - 25)$	
	= 25 725 J	W1
	Total loss of energy = $1237.5 + 25 725 = 26 962.5$ J	
	Cyclist's loss of energy provides some of the work needed to overcome resistances – the rest is provided by the cyclist doing work	
	Work done by cyclist = $29 400 - 26 962.5$	M1 W1
	Work done by cyclist = 2437.5	
	= 2440 J	W1
		9

		AVAILABLE MARKS
4	(i)	
		
	$P = Fv \quad \therefore \text{Tractive force} = \frac{P}{v}$	M1
	Max speed $\Rightarrow$ forces balance	M1
	$(a + bv) = \frac{48000}{50}$	W1
	$a + 50b = 960$	W1
	(ii)	
		
	Max speed, forces balanced	M1
	$(a + b(30)) + 2000 g \left(\frac{1}{25}\right) = \frac{48000}{30}$	MW3
	$a + 30b = 800$	
	Solving equations simultaneously, $a = 560, b = 8$	MW1
	(iii) $560 + 8(40) \leftarrow \boxed{\quad} \rightarrow \frac{48000}{40}$	
	Resultant = 320 N	MW1
	$F = ma$	M1
	$320 = 2000 (a) \quad a = 0.16 \text{ m s}^{-2}$	W1
		12

5	(i) time to fall 100 m	$s = ut + \frac{1}{2} at^2$ $100 = 0 + \frac{1}{2} (9.8)t^2$ $t = 4.5175$	M1	AVAILABLE MARKS
	horizontally,	$s = ut$		W1
		$s = 49 \times 4.5175$	M1	
		$s = 221 \text{ m}$	W1	
	(ii) speed vertically	$v = u + at$	M1	
		$v = 0 + 9.8 (4.5175)$		
		$v = 44.27 \text{ m s}^{-1}$	W1	
	Horizontally remains $49 \text{ m s}^{-1}$		M1	
	Speed $= \sqrt{49^2 + 44.27^2} = 66.0 \text{ m s}^{-1}$		M1 W1	
	(iii) logical assumption		MW1	10

6 (i)  $(v^2 + k^2)$    $\rightarrow 5k^2$

AVAILABLE MARKS

Maximum speed when  $v^2 + k^2 = 5k^2$ 

M1

$$v^2 = 4k^2$$

$$v = 2k$$

W1

(ii)  $5k^2 \leftarrow (v^2 + k^2)$  

Using  $F = ma$ 

M1

$$-(5k^2 + v^2 + k^2) = M v \frac{dv}{dx}$$

W1

$$v^2 + 6k^2 = -M v \frac{dv}{dx}$$

W1

(iii) Separate variables

$$\int \frac{1}{M} dx = \int \frac{-v}{v^2 + 6k^2} dv$$

M2 W1

$$\frac{1}{M} x = -\frac{1}{2} \ln(v^2 + 6k^2) + c$$

W2

$$x = 0, v = 2k$$

M1

$$0 = -\frac{1}{2} \ln((2k)^2 + 6k^2) + c$$

$$c = \frac{1}{2} \ln(10k^2)$$

W1

$$\frac{1}{M} x = \frac{1}{2} \ln(10k^2) - \frac{1}{2} \ln(v^2 + 6k^2) + c$$

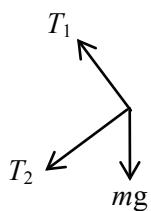
$$\frac{1}{M} x = \frac{1}{2} \ln\left(\frac{10k^2}{v^2 + 6k^2}\right)$$

$$\text{At } v = 0 \quad x = \frac{M}{2} \ln \frac{5}{3}$$

MW1

13

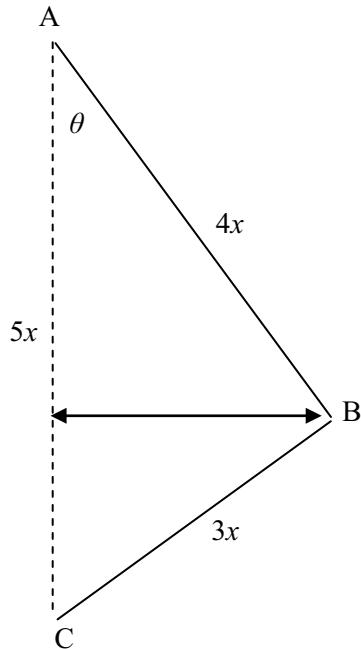
7 (i)



MW1

AVAILABLE MARKS

(ii)



$$\text{Radius} = 4x \sin \theta$$

M1

$$\sin \theta = \frac{3x}{5x} = \frac{3}{5}$$

$$\text{Radius} = 4x \left(\frac{3}{5}\right)$$

$$= \frac{12x}{5}$$

W1

(iii) Resolving vertically

M1

$$T_1 \cos \theta = T_2 \sin \theta + mg$$

W1

$$T_1 \left(\frac{4}{5}\right) = T_2 \left(\frac{3}{5}\right) + mg$$

MW1

$$4T_1 - 3T_2 = 5mg$$

Resolving horizontally

M1

$$T_1 \sin \theta + T_2 \cos \theta = mr\omega^2$$

W1

M1

$$T_1 \left(\frac{3}{5}\right) + T_2 \left(\frac{4}{5}\right) = m \left(\frac{12x}{5}\right) \left(\frac{5g}{6x}\right)$$

W1

$$3T_1 + 4T_2 = 10mg$$

Solving simultaneously

$$T_1 = \text{tension in AB} = 2mg$$

MW1

$$T_2 = \text{tension in BC} = mg$$

MW1

12

Total

75