QQQ – Mechanics Year 1 – Chapter 11 – Variable Acceleration (Calculus) (Version 1)

Total Marks: 25

(25 = Platinum, 23 = Gold, 20 = Silver, 17 = Bronze)

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1. A particle moves along a straight line. Its velocity v m s^{-1} at time t s is given by $v = 2t + 0.6t^2$.

Find an expression for the acceleration of the particle at time t. **[2]**

(Total 2 marks)

2. The displacement, r metres, of a particle at time t seconds is

$$r = 6t - 2t^2$$

(a) Find the value of r when $t = 4$ **[1 mark]**

(b) Determine the range of values of t for which the displacement is positive. **[2 marks]**

(Total 3 marks)

3. A particle moves in a straight line with acceleration a m s^{-2}, at time t seconds, where

$$a = 10 - 6t$$

The particle's velocity, v m s^{-1}, and displacement, r metres, are both initially zero.

Show that

$$r = t^2(5 - t)$$

Fully justify your answer. **[4 marks]**

(Total 4 marks)

4. A sports scientist is modelling the speed of an athlete who ran a 100-metre race.

The speed, v m s^{-1}, of the athlete at time t seconds after the start of the 100-metre race is given by

$$v = 1.8 + 3.8t - 0.25t^2$$

(a) State the initial speed of the athlete according to the model. **[1 mark]**

(b) **(i)** Find an expression, in terms of t, for the acceleration of the athlete. **[2 marks]**

(ii) Hence find the maximum speed of the athlete.

Fully justify your answer. **[4 marks]**

(c) The official maximum speed recorded, by the scientist, for the athlete was 12.4 m s^{-1}

Evaluate the accuracy of the model used by the scientist. **[1 mark]**

(Total 8 marks)

5.

In this question you must show all stages of your working.

Solutions relying entirely on calculator technology are not acceptable.

A fixed point O lies on a straight line.

A particle P moves along the straight line such that at time t seconds, $t \geqslant 0$, after passing through O, the velocity of P, v m s^{-1}, is modelled as

$$v = 15 - t^2 - 2t$$

(a) Verify that P comes to instantaneous rest when $t = 3$ **(1)**

(b) Find the magnitude of the acceleration of P when $t = 3$ **(3)**

(c) Find the total distance travelled by P in the interval $0 \leqslant t \leqslant 4$ **(4)**

(Total 8 marks)

Solutions

1. OCR MEI June 2023 Paper 1 Q1

Scheme	Marks	AO
$a = \dfrac{\mathrm{d}v}{\mathrm{d}t} = 2 + 1.2t \text{ m s}^{-2}$	M1 A1	1.1a 1.1b
	[2]	

Notes

M1: Attempt to differentiate. Note $2 + 0.6t$ is obtained by division so award M0A0 if seen.

A1: cao

2. AQA June 2024 Paper 2 Q14

Mark scheme (a)

Scheme	Marks	AO
Obtains -8	B1	1.1b
	(1)	

Typical solution

-8

Mark scheme (b)

Scheme	Marks	AO
Forms an equation or inequality to compare $6t - 2t^2$ with 0 PI by $6t = 2t^2, 6t > 2t^2$ or $t = 0$ and $t = 3$	M1	3.1a
Obtains $0 < t < 3$ OE	A1	1.1b
	(2)	
	(3 marks)	

Typical solution

$$-2t^2 + 6t > 0$$

So $0 < t < 3$

3. AQA June 2024 Paper 1 Q17

Scheme	Marks	AO
Integrates to find v with at least one non-constant term correct	M1	3.4
Obtains fully correct expression for v Must include $+c$ or state that $c = 0$	A1	1.1b
Integrates their v with at least one term correct	M1	1.1a
Completes reasoned argument to show $r = t^2(5 - t)$ Explanation for both constants of integration $= 0$ must be given	R1	2.1
	(4 marks)	

Typical solution

$$v = \int 10 - 6t \, \mathrm{d}t$$

$$v = 10t - 3t^2 + c$$

When $t = 0, v = 0$ therefore $c = 0$

$$r = \int 10t - 3t^2 \, \mathrm{d}t$$

$$r = 5t^2 - t^3 + c$$

When $t = 0, r = 0$ therefore $c = 0$

So

$$r = t^2(5 - t)$$

4. AQA June 2025 Paper 1 Q20

Mark scheme (a)

Scheme	Marks	AO
States 1.8 m s^{-1} Condone missing units	B1	3.4
	(1)	

Typical solution

1.8 m s^{-1}

Mark scheme (b)

Scheme	Marks	AO
(i) Differentiates to find expression for acceleration with at least one term correct	M1	3.4
Obtains $3.8 - 0.5t$	A1	1.1b
	(2)	
(ii) Sets their expression for acceleration equal to 0	M1	3.4
Obtains $t = 7.6$	A1	1.1b
Substitutes their positive value for t into $v = 1.8 + 3.8t - 0.25t^2$	M1	3.3
Obtains AWRT 16.2 m s^{-1} CSO Condone missing units	A1	1.1b
	(4)	

Typical solution

(i)

$$v = 1.8 + 3.8t - 0.25t^2$$

$$a = \frac{\mathrm{d}v}{\mathrm{d}t} = 3.8 - 0.5t$$

(ii)

Max v when $a = 0$

$$3.8 - 0.5t = 0$$

$$t = 7.6$$

$$\max v = 1.8 + 3.8(7.6) - 0.25(7.6)^2$$

$= 16.24$ m s^{-1}

Mark scheme (c)

Scheme	Marks	AO
Compares their maximum speed and 12.4 and concludes appropriately that the values are not approximately equal and the model is not accurate FT their maximum speed Accept valid comments about the initial speed being unrealistic	E1F	3.5a
	(1)	
	(8 marks)	

Typical solution

$$16.2 > 12.4$$

Model overestimates the speed significantly so not an accurate model

5. Edexcel June 2023 Mechanics Q3

Mark scheme (a)

Scheme	Marks	AO
$15 - 3^2 - 2 \times 3 = 0$ *	B1*	1.1b
	(1)	

Notes

B1* Correct expression, correctly evaluated to give 0
OR $0 = 15 - t^2 - 2t$
$t = 3$

Mark scheme (b)

Scheme	Marks	AO
Differentiate v wrt t	M1	2.1
$-2t - 2$	A1	1.1b
$8\ (\mathrm{m\,s^{-2}})$	A1	1.1b

	(3)	

Notes

M1 Differentiate v, with at least two powers decreasing by 1

A1 Correct expression

A1 cao (must be positive)

N.B. If they give 8 as their answer, without any working, this can score all 3 marks.

Mark scheme (c)

Scheme	Marks	AO
Integrate v w.r.t. t	M1	1.1b
$15t - \frac{1}{3}t^3 - t^2$	A1	1.1b
Total distance = $\left[15t - \frac{1}{3}t^3 - t^2\right]_0^3 - \left[15t - \frac{1}{3}t^3 - t^2\right]_3^4$ **OR** $s_3 + (s_3 - s_4)$ where s_3 means the value of their integral when $t = 3$. **N.B.** Allow the negative of this.	M1	3.1a
$\frac{94}{3}$ (m)	A1	1.1b
	(4)	
	(8 marks)	

Notes

M1 Integrate v, with at least two powers increasing by 1 (allow if only two terms integrated) .

A1 Correct expression. Ignore $(+C)$

M1 Complete method to find the total distance or displacement

A1 Accept 31(m) or better, must be positive

N.B. If the indefinite integral $(15t - \frac{1}{3}t^3 - t^2)$ is never seen, they score nothing, even if the correct answer appears, as this indicates they have used a calculator to do the whole question.