

QQQ - Further Mechanics 2 - Chapter 4 - Kinematics (Version 2)

Total Marks: 24

(24 = Platinum, 22 = Gold, 19 = Silver, 16 = Bronze)

1. A particle P is moving along the positive x -axis. When the displacement of P from the origin is x metres, the velocity of P is $v \text{ m s}^{-1}$ and the acceleration of P is $9x \text{ m s}^{-2}$.

When $x = 2$, $v = 6$

Show that $v^2 = 9x^2$. (4)

(Total 4 marks)

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2. A particle P is moving along the positive x -axis. At time $t = 0$, P is at the origin O . At time t seconds, P is x metres from O and has velocity $v = 2e^{-x} \text{ m s}^{-1}$ in the direction of x increasing.

(a) Find the acceleration of P in terms of x . (3)

(b) Find x in terms of t . (6)

(Total 9 marks)

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3. A particle P moves on the x -axis. At time t seconds the velocity of P is $v \text{ m s}^{-1}$ in the positive x -direction, where

$$v = 3 - \sqrt{2t + 1} \quad t \geq 0$$

(a) Find the value of t when P is at instantaneous rest. (2)

The acceleration of P at time t seconds is $a \text{ m s}^{-2}$ in the positive x -direction.

(b) Show that $a = \frac{1}{v - 3}$ (3)

(c) Find the speed of P when it is decelerating at $\frac{4}{3} \text{ m s}^{-2}$ (2)

(d) Find the total distance travelled by P between $t = 0$ and $t = \frac{15}{2}$
[Solutions relying on calculator technology are not acceptable.] (4)

(Total 11 marks)

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Solutions

1.

Scheme	Marks
$v \frac{dv}{dx} = 9x$	M1
$\frac{1}{2}v^2 = 9x \quad (+c)$	A1
$v^2 = 9x^2 + c$	M1dep
$x = 2 \quad v = 6 \quad 36 = 9 \times 4 + c \Rightarrow c = 0$	
$v^2 = 9x^2$	A1

2.

Mark scheme (a)

Scheme	Marks
Use of $a = v \frac{dv}{dx}$ or $a = \frac{d}{dx} \left(\frac{1}{2}v^2 \right)$	M1
$a = 2e^{-x} \cdot -2e^{-x}$ or $v^2 = 4e^{-2x}$	A1
$a = -4e^{-2x}$	A1
	(3)

Mark scheme (b)

Scheme	Marks
Separate the variables and attempt to integrate:	M1
$\int 2 dt = \int e^x dx$	
$2t = e^x + C$	A1A1
$t = 0, x = 0 \Rightarrow C = -1, \quad 2t = e^x - 1$	M1A1
$x = \ln(2t + 1)$	A1
	(6)

(9 marks)

3.

Mark scheme (a)

Scheme	Marks	AO
$0 = 3 - \sqrt{2t + 1}$	M1	2.1
$t = 4$	A1	1.1b
	(2)	

Notes

M1: Correct equation

A1: cao

Mark scheme (b)

Scheme	Marks	AO
Differentiate v wrt t	M1	2.1
$a = \frac{-1}{\sqrt{2t + 1}}$	A1	1.1b
$a = \frac{1}{v - 3}^*$	A1*	2.2a
	(3)	

Notes

M1: Both powers decreasing by 1

A1: Correct expression

A1*: Given answer correctly obtained including " $a =$ " seen in solution

Mark scheme (c)

Scheme	Marks	AO
$-\frac{4}{3} = \frac{1}{v - 3}$	M1	2.1
$v = 2.25 \text{ (m s}^{-1}\text{)}$	A1	1.1b

	(2)	
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Notes

M1: Correct equation

A1: cao

Mark scheme (d)

Scheme	Marks	AO
Integrate v wrt t	M1	2.1
$3t - \frac{1}{3}(2t + 1)^{\frac{3}{2}} (+C)$	A1	1.1b
$\left[3t - \frac{1}{3}(2t + 1)^{\frac{3}{2}}\right]_0^4 - \left[3t - \frac{1}{3}(2t + 1)^{\frac{3}{2}}\right]_4^{7.5}$	M1	3.1a
$5\frac{1}{6} \text{ (m)}$	A1	1.1b
	(4)	
	(11 marks)	

Notes

M1: Both powers increasing by 1

A1: Correct expression

M1: Correct method by considering change of direction

A1: Accept 5.2 or better