Question	Scheme	Marks	AOs
6(a)	$2m^2+5m+2=0 \Rightarrow m=-\frac{1}{2},-2$	M1	3.4
	$x=Ae^{-0.5t}+Be^{-2t}$	A1	1.1b
	PI is of the form $x = pt + q$	B1	1.1b
	$\frac{dx}{dt}=p,\ \frac{d^2x}{dt^2}=0 \Rightarrow 5p+2pt+2q=4t+12 \Rightarrow p=...,q=...$	M1	3.4
	$p=2,q=1$	A1	1.1b
	$x=Ae^{-0.5t}+Be^{-2t}+2t+1$	A1ft	1.1b
		(6)	
(b)	$t=0,\ x=3 \Rightarrow 3=A+B+1$	M1	3.4
	$\frac{dx}{dt}=-0.5Ae^{-0.5t}-2Be^{-2t}+2$ $t=0,\ \frac{dx}{dt}=-2 \Rightarrow -\frac{1}{2}A-2B+2=-2$ $\Rightarrow A=...,\ B=...$	M1	3.4
	$x=2e^{-2t}+2t+1$	A1	1.1b
		(3)	
(c)(i)	$\frac{dx}{dt}=-4e^{-2t}+2$	M1	3.1b
	$e^{-2t}=\frac{1}{2} \Rightarrow -2t=\ln\frac{1}{2} \Rightarrow t=\frac{1}{2}\ln 2$	dM1	2.1
	$x=2e^{-2t}+2t+1=1+\ln 2+1=2+\ln 2$*	A1*	1.1b
(c)(ii)	$\frac{d^2x}{dt^2}=8e^{-2t}$ is > 0 for all values of *t* so distance is a minimum	B1ft	2.4
		(4)	
(d)	Examples: For large values of *t*, $\left[e^{-2t}\to 0 \Rightarrow\right] x \to 2t+1$ so constant speed For large values of *t*, $\left[e^{-2t}\to 0 \Rightarrow\right] \frac{dx}{dt} \to 2$ so constant speed For large values of *t*, $\left[e^{-2t}\to 0 \Rightarrow\right] \frac{d^2x}{dt^2} \to 0$ so constant speed Conclusion: so the model is suitable	B1ft	3.2b
		(1)	
		(14 marks)	

Notes

(a)

M1: Attempts to solve $2m^2+5m+2=0$, usual rules apply for solving a quadratic equation.

A1: Correct CF. Do not need "*x* =" here, but must be in terms of *t*

B1: Correct form for the PI i.e. $x = pt + q$ or $x = at^2 + bt + c$

M1: Differentiates their PI (of the forms $x = pt + q$ or $x = at^2 + bt + c$) twice and substitutes into the given differential equation finding values for their constants to obtain a PI of the form $pt + q$, $p, q \neq 0$

A1: Correct PI

A1ft: Correct GS or correct ft GS, which is the sum of their CF and PI. This is dependent on achieving both previous M marks. **Must have *x* =** and their GS must be in terms of t.

(b)
M1: Substitutes $x = 3$ when $t = 0$ into their GS to establish an equation in A and B, allow minor slips if the intention is clear.

M1: Differentiates their answer to part (a) which must be in terms of t only, and sets = –2 with t = 0 to establish another equation in A and B and solves simultaneously to find A and B.
Do not be concerned about how their simultaneous equations are solved; award this mark if they then go on to write values for A and B.
Functions which require the use of product rule or trigonometric functions must be differentiated appropriately.

A1: Correct PS. **Need "*x* ="** here, their answer must be in terms of t and no other variable.

(c) Mark (i) and (ii) together but only award for work done in (c)
(i)
M1: Differentiates their Particular Solution of the form $x = ae^{-kt} + bt + c$ where c may be 0 to obtain an expression of the form $\mathrm{C}\mathrm{e}^{-kt} + D$

dM1: Solves an equation of the form $\mathrm{C}\mathrm{e}^{-kt} + D = 0, \quad C \times D < 0$, to obtain $t = -\frac{1}{k}\ln\left(\frac{-D}{C}\right)$

A1*: Substitutes $t = \frac{1}{2}\ln 2$ oe to obtain the printed answer with no errors.

Condone going from $2\mathrm{e}^{-2\left(\frac{1}{2}\ln 2\right)} + 2\left(\frac{1}{2}\ln 2\right) + 1 = 2 + \ln 2$

(c)(ii)
B1ft: Obtains a second derivative of the form $\frac{\mathrm{d}^2x}{\mathrm{d}t^2} = \lambda\mathrm{e}^{-\mu t}, \quad \lambda, \mu > 0$ **and** makes a conclusion e.g.

- $\frac{\mathrm{d}^2x}{\mathrm{d}t^2} > 0$ (for all values of t) hence minimum.
- or substitutes their value of t (even if incorrect) and states $\frac{\mathrm{d}^2x}{\mathrm{d}t^2} > 0$ hence minimum

(d)
B1ft: Dependent on having obtained a Particular Solution of the form $\mathrm{f}(t) + bt + c$ where f(t) only has terms in ae^{-kt} where $k > 0$ and $a, b \neq 0$
This mark is awarded for the candidate demonstrating that in the model for "large values" or "as $t \to \infty$", the value of their $e^{-kt} \to 0$, so there is constant speed **and** states that the model is suitable, or equivalent statement. (See scheme for examples)