Mechanics Year 1 (AS) exam questions

NOTE:
Please be aware that in the Year 12 collections, you will find questions from the Year 13 papers. However, these questions are intentionally included because they align with Year 12 content and topics.

Ch. 8: Modelling in Mechanics **2**
Ch. 9: Constant Acceleration **3**
June 2024 Question 2 (A-level) 3
June 2024 Question 1 6
June 2023 Question 2 8
June 2023 Question 1 10
June 2023 Question 1 (A-Level) 12
June 2022 Question 1 13
June 2022 Question 2 16
November 2021 question 1 19
November 2020 question 1 21
June 2019 question 1 24
June 2018 Question 6 26
June 2018 Question 7 27
Ch. 10: Forces and Motion **29**
June 2024 Question 4 29
June 2024 Question 3 32
June 2023 Question 4 33
June 2022 Question 4 35
November 2021 question 3 37
November 2020 question 2 40
June 2019 question 2 42
June 2018 Question 9 44
Ch. 11: Variable Acceleration **46**
June 2024 Question 2 46
June 2023 Question 3 48
June 2022 Question 3 50
November 2021 question 2 52
November 2020 question 3 54
June 2019 question 3 56
June 2018 Question 8 57

Arancha Ruiz

Ch. 8: Modelling in Mechanics

No exam questions, just some 1 or 2 marks in a bigger question, asking you about modelling assumptions or how you would improve a model.

Arancha Ruiz

Ch. 9: Constant Acceleration

June 2024 Question 2 (A-level)

2.

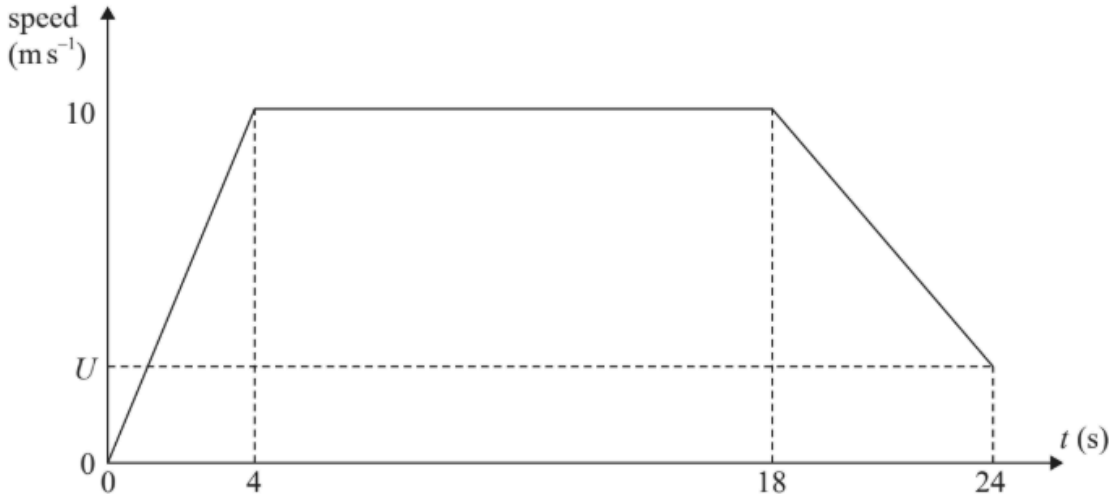


Figure 2

Figure 2 shows a speed-time graph for a model of the motion of an athlete running a **200 m** race in 24 s.

The athlete

- starts from rest at time $t = 0$ and accelerates at a constant rate, reaching a speed of $10\,\text{m s}^{-1}$ at $t = 4$
- then moves at a constant speed of $10\,\text{m s}^{-1}$ from $t = 4$ to $t = 18$
- then decelerates at a constant rate from $t = 18$ to $t = 24$, crossing the finishing line with speed $U\,\text{m s}^{-1}$

Using the model,

(a) find the acceleration of the athlete during the first 4 s of the race, stating the units of your answer,

(2)

(b) find the distance covered by the athlete during the first 18 s of the race,

(3)

(c) find the value of U.

(3)

ANSWER

Question	Scheme	Marks	AOs
2(a)	$\frac{10}{4}$	M1	3.4
	2.5, $\frac{5}{2}, \frac{10}{4}$ m s^{-2} units needed.	A1	1.1b
		(2)	
2(b)	Find the area, with correct structure, from $t = 0$ to 18	M1	3.1b
	$\frac{1}{2}\times 4\times 10+(14\times 10)$ triangle + rectangle **or** $\frac{1}{2}\times 10\times(14+18)$ trapezium **or** $(18\times 10)-\frac{1}{2}\times 4\times 10$ rectangle – triangle **N.B.** $\frac{1}{2}\times 4\times 10$ may be replaced by $\frac{1}{2}\times 2.5\times 4^2$ using $s=ut+\frac{1}{2}at^2$ or by $\frac{10^2-0^2}{2\times 2.5}$ using $v^2=u^2+2as$	A1	1.1b
	160 (m)	A1	1.1b
		(3)	

2(c)	Using area, from $t = 18$ to $t = 24$, $= (200 - \text{their (b)})$ with correct structure **OR** $s =$ $(200 - \text{their (b)})$, using *suvat* to find s **N.B.** If their (b) is incorrect and they don't use it, allow a correct restart.	M1	3.1b
	$6U + \frac{1}{2} \times 6 \times (10 - U) = 200 - \text{their (b)}$ rectangle + triangle **or** $\frac{1}{2} \times 6 \times (10 + U) = 200 - \text{their (b)}$ trapezium $\left(s = \left(\frac{u+v}{2}\right)t\right)$ **or** $(6 \times 10) - \frac{1}{2} \times 6 \times (10 - U) = 200 - \text{their (b)}$ rectangle − triangle **or** $(10 \times 6) + \frac{1}{2}\left(-\frac{(10-U)}{6}\right) \times 6^2 = 200 - \text{their (b)}$ $s = ut + \frac{1}{2}at^2$ **or** $(U \times 6) - \frac{1}{2}\left(-\frac{(10-U)}{6}\right) \times 6^2 = 200 - \text{their (b)}$ $s = vt - \frac{1}{2}at^2$ **N.B.** Two stage *suvat* method: $(10 \times 6) + \frac{1}{2}a \times 6^2 = 200 - \text{their (b)} \Rightarrow$ **AND** $U = 10 + 6 \times$ their a	A1**ft**	1.1b

	$\frac{10}{3} = 3\frac{1}{3}$ oe	A1	1.1b
		(3)	
			(8 marks)

June 2024 Question 1

1.

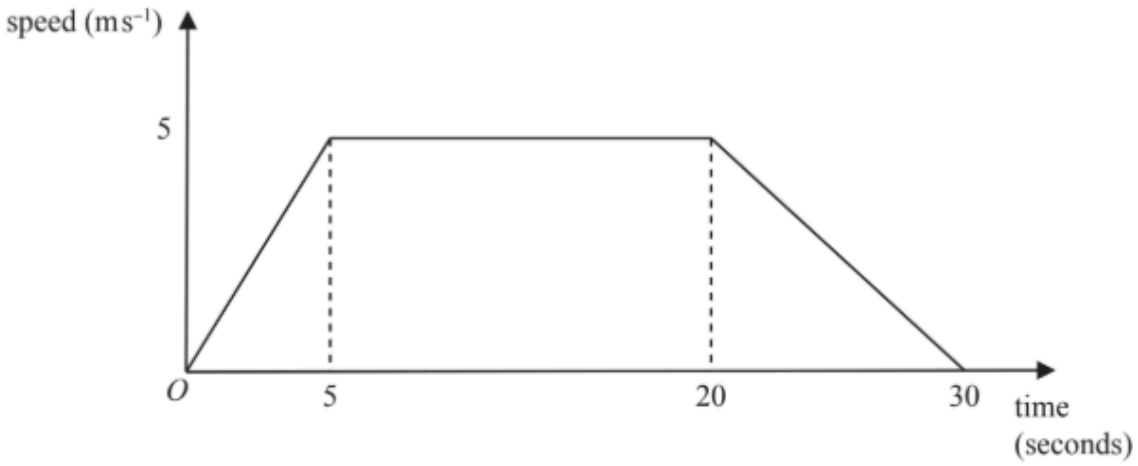


Figure 1

Figure 1 shows the speed-time graph for the journey of a car moving in a long queue of traffic on a straight horizontal road.

At time $t = 0$, the car is at rest at the point A.

The car then accelerates uniformly for 5 seconds until it reaches a speed of $5\,\text{ms}^{-1}$

For the next 15 seconds the car travels at a constant speed of $5\,\text{ms}^{-1}$

The car then decelerates uniformly until it comes to rest at the point B.

The total journey time is 30 seconds.

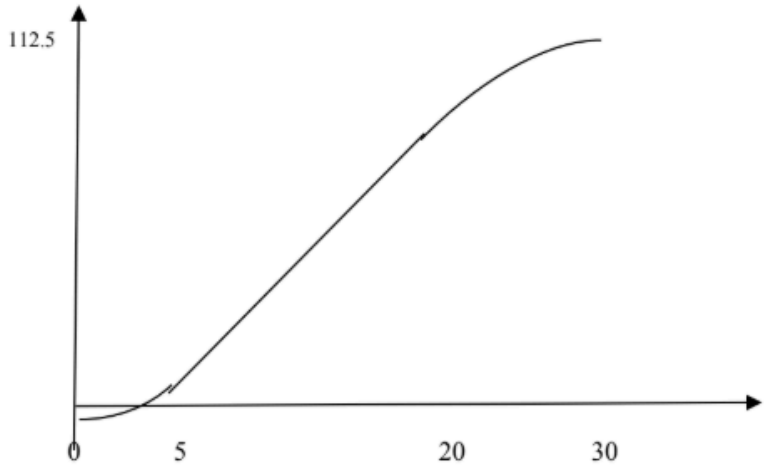
(a) Find the distance AB.

(3)

(b) Sketch a distance-time graph for the journey of the car from A to B.

(3)

ANSWER

Question	Scheme	Marks	AOs
1(a)	Complete method to find AB	M1	3.1b
	$=(\frac{1}{2}\times5\times5)+(5\times15)+(\frac{1}{2}\times5\times10)$ or $=\frac{1}{2}(30+15)\times5$ or $=(\frac{1}{2}\times5\times5)+\frac{1}{2}(25+15)\times5$ or $=\frac{1}{2}(20+15)\times5+(\frac{1}{2}\times5\times10)$ or $=(30\times5)-(\frac{1}{2}\times5\times5)-(\frac{1}{2}\times5\times10)$	A1	1.1b
	$=112.5\,(\text{m})$	A1	1.1b
		(3)	
(b)		B1 B1 B1	1.1b 1.1b 1.1b
		(3)	
			(6 marks)

June 2023 Question 2

2. A small stone is projected vertically upwards with speed $39.2\,\text{m s}^{-1}$ from a point O.

The stone is modelled as a particle moving freely under gravity from when it is projected until it hits the ground 10 s later.

Using the model, find

(a) the height of O above the ground,

(3)

(b) the total length of time for which the speed of the stone is less than or equal to $24.5\,\text{m s}^{-1}$

(3)

(c) State one refinement that could be made to the model that would make your answer to part (a) more accurate.

(1)

ANSWER

Question	Scheme	Marks	AOs
2(a)	Attempt to find the displacement after 10 s	M1	3.1b
	$39.2\times10-\frac{1}{2}g\times10^2$ **OR** $-39.2\times10+\frac{1}{2}g\times10^2$	A1	1.1b
	98 (m) (must be positive)	A1	1.1b
		(3)	
2(b)	Complete method to find either half the time or the full time	M1	3.1b
	Correct equation e.g. $0=24.5-gt$ **OR** $-24.5=24.5-gt$	A1	1.1b
	5 (s)	A1	1.1b
		(3)	
2(c)	e.g. (include) air resistance	B1	3.5c
		(1)	
			(7 marks)

June 2023 Question 1

1.

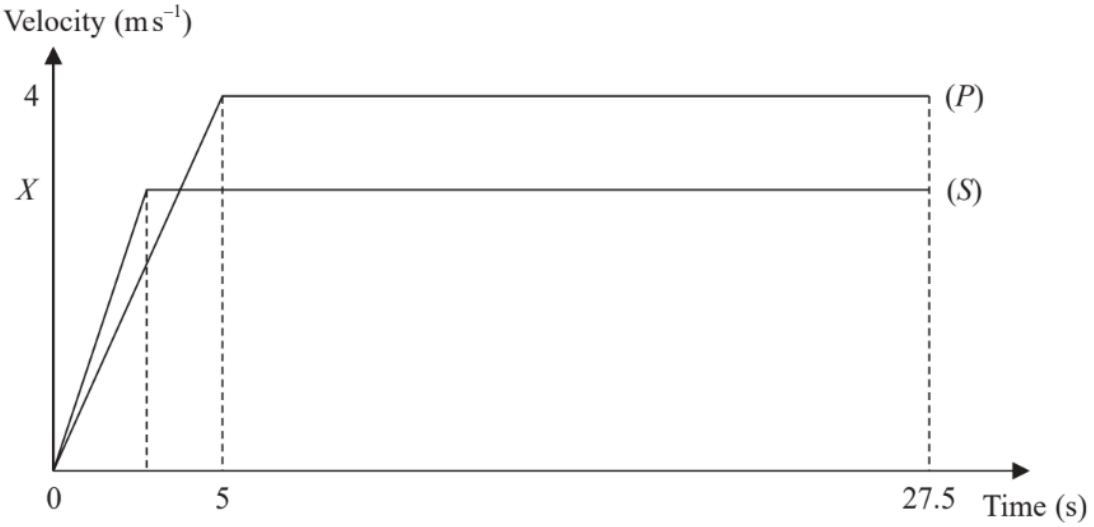


Figure 1

Two children, Pat (P) and Sam (S), run a race along a straight horizontal track.

Both children start from rest at the same time and cross the finish line at the same time.

In a model of the motion:

Pat accelerates at a constant rate from rest for 5 s until reaching a speed of 4 m s^{-1} and then maintains a constant speed of 4 m s^{-1} until crossing the finish line.

Both children take 27.5 s to complete the race.

The velocity-time graphs shown in Figure 1 describe the model of the motion of each child from the instant they start to the instant they cross the finish line together.

Using the model,

(a) explain why the areas under the two graphs are equal,

(1)

(b) find the acceleration of Pat during the first 5 seconds,

(1)

(c) find, in metres, the length of the race,

(2)

(d) find the value of X, giving your answer to 3 significant figures.

(4)

ANSWER

Question	Scheme	Marks	AOs
1(a)	Because the distances travelled or displacements are equal oe. If they mention the times are the same as well, ignore it.	B1	2.4
		(1)	
1(b)	0.8 or 4/5 ($\mathrm{m\,s^{-2}}$)	B1	1.1b
		(1)	
1(c)	$\frac{1}{2}\times 5\times 4+(4\times 22.5)$ **OR** $\frac{1}{2}(27.5+22.5)\times 4$ **OR** $27.5\times 4-\frac{1}{2}\times 5\times 4$	M1	3.1b
	100 (m)	A1	1.1b
		(2)	
1(d)	Total area under graph = their answer for part (c)	M1	3.1b
	$\frac{1}{2}X\times X+X(27.5-X)=100$	A1**ft**	1.1b
	OR $\frac{1}{2}(27.5+27.5-X)\times X=100$ **OR** $27.5X-\frac{1}{2}X^2=100$	A1**ft**	1.1b
	X = 3.92 to 3sf	A1	1.1b
		(4)	
			(8 marks)

June 2023 Question 1 (A-Level)

1. A car is initially at rest on a straight horizontal road.

The car then accelerates along the road with a constant acceleration of $3.2\,\text{m s}^{-2}$

Find

(a) the speed of the car after 5 s,

(1)

(b) the distance travelled by the car in the first 5 s.

(2)

ANSWER

Question	Scheme	Marks	AOs
1(a)	$16\ (\text{m s}^{-1})$ seen as the answer	B1	1.1b
		(1)	
1(b)	$s=\frac{1}{2}\times3.2\times5^2$ **OR** $s=\frac{(0+16)}{2}\times5$ **OR** $s=(16\times5)-\frac{1}{2}\times3.2\times5^2$ **OR** $16^2=2\times3.2\times s$ **OR** from a *v*-*t* graph, $s=\frac{1}{2}\times5\times16$	M1	3.1b
	$s = 40$ (m)	A1	1.1b
		(2)	
			(3 marks)

June 2022 Question 1

1. The point A is 1.8 m vertically above horizontal ground.

At time $t = 0$, a small stone is projected vertically upwards with speed $U\,\text{m s}^{-1}$ from the point A.

At time $t = T$ seconds, the stone hits the ground.

The speed of the stone as it hits the ground is $10\,\text{m s}^{-1}$

In an initial model of the motion of the stone as it moves from A to where it hits the ground

- the stone is modelled as a particle moving freely under gravity
- **the acceleration due to gravity is modelled as having magnitude $10\,\text{m s}^{-2}$**

Using the model,

(a) find the value of U,

(3)

(b) find the value of T.

(2)

(c) Suggest one refinement, apart from including air resistance, that would make the model more realistic.

(1)

In reality the stone will not move freely under gravity and will be subject to air resistance.

(d) Explain how this would affect your answer to part (a).

(1)

ANSWER

Question	Scheme	Marks	AOs
1(a)	Complete method to produce an equation in U only	M1	3.4
	e.g. $10^2 = U^2 + 2 \times g \times 1.8$ oe	A1	1.1b
	OR a **complete** method where they find T first and use it to find an equation in U only M1		
	A correct equation in U only. A1		
	$U = 8$ (only this answer)	A1	1.1b
		(3)	

Video solution:

https://youtu.be/vSSdZC7COwA

(b)	Complete method to find an equation in T only: $10 = -8 + gT$ or $1.8 = 10T - \frac{1}{2}gT^2$ or $1.8 = \frac{(-8+10)}{2}T$ or $1.8 = -8T + \frac{1}{2}gT^2$ **OR** a **complete** method if they split the time. In both cases, the M1 is only earned on the final line when they try to add the two times to give an equation in T. **ALT 1**: time up + time down e.g. $0 = 8 - gt_{UP}$ $(\Rightarrow t_{UP} = 0.8)$ $h_{UP} = \frac{(8+0)}{2} \times 0.8$ $(= 3.2)$ $(h_{UP} + 1.8) = \frac{(0+10)}{2} \times t_{DOWN}$ $(\Rightarrow t_{DOWN} = 1)$ $T = t_{UP} + t_{DOWN}$ **ALT 2:** time to A + time from A to ground e.g. $8 = -8 + gt_A$ $(\Rightarrow t_A = 1.6)$ $1.8 = \frac{(8+10)}{2} \times t_{AG}$ $(\Rightarrow t_{AG} = 0.2)$ $T = t_A + t_{AG}$	M1	3.4
	$T = 1.8$ oe e.g. 9/5	A1	1.1b
		(2)	

		(1)	
(d)	U would be greater. Allow without U, e.g it would be greater, or just 'greater' oe ISW	B1	3.5a
		(1)	
			(7 marks)

Video solution:

AS Maths June 2022 Question 1 Mechanics paper 22 Edexcel

June 2022 Question 2

2. A train travels along a straight horizontal track from station P to station Q.

In a model of the motion of the train, at time $t = 0$ the train starts from rest at P, and moves with constant acceleration until it reaches its maximum speed of $25\,\text{m s}^{-1}$

The train then travels at this constant speed of $25\,\text{m s}^{-1}$ before finally moving with constant deceleration until it comes to rest at Q.

The time spent decelerating is four times the time spent accelerating.

The journey from P to Q takes 700 s.

Using the model,

(a) sketch a speed-time graph for the motion of the train between the two stations P and Q.

(1)

The distance between the two stations is 15 km.

Using the model,

(b) show that the time spent accelerating by the train is 40 s,

(3)

(c) find the acceleration, in m s^{-2}, of the train,

(1)

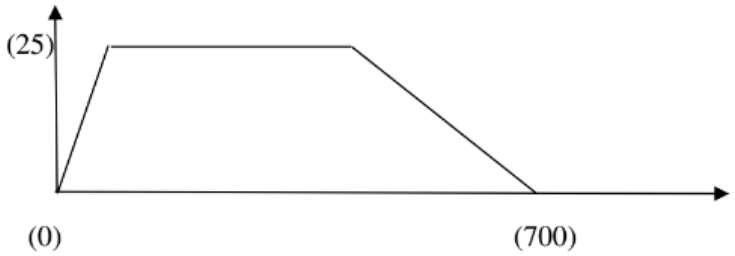
(d) find the speed of the train 572 s after leaving P.

(2)

(e) State one limitation of the model which could affect your answers to parts (b) and (c).

(1)

ANSWER

Question	Scheme	Marks	AOs
2(a)		B1	1.1b
		(1)	
(b)	Using *total* area = 15000 to set up an *equation* in **one unknown** Or they may use *suvat* on one or more sections (but must still be considering *all* sections) Allow an attempt at a clear explicit verification using $t = 40$ e.g. the following would score M1A1A1*: $4\times40=160$ then $700-40-160=500$ $\frac{(700+500)}{2}\times25=15000=15$ km Withhold A1* if they don't include = 15 km **N.B.** M0 if a single *suvat* formula is used for the whole journey.	M1	3.4

	$\frac{1}{2}(700+700-t-4t)\times 25=15000$ **OR** $\frac{1}{2}\times 25\times t+25(700-t-4t)+\frac{1}{2}\times 25\times 4t=15000$	A1	1.1b
	$t=40$ (s)*	A1*	1.1b
		(3)	
(c)	0.63 or 0.625 or $\frac{5}{8}$ oe ($m\,s^{-2}$) isw	B1	1.1b/ (2.2a)
		(1)	
(d)	Complete method to find the speed or velocity at $t=572$ e.g $\pm\left(25-(32\times\frac{5}{32})\right)$ or $\pm\left(128\times\frac{5}{32}\right)$ oe	M1	3.1b
	20 ($m\,s^{-1}$)	A1	1.1b
		(2)	
(e)	e.g. (the train) cannot instantaneously change acceleration, (the train) won't move with <u>constant</u> acceleration , (the train) won't move with <u>constant</u> speed Allow negatives of these:	B1	3.5b
	e.g. (The train) moving at constant speed, or just 'constant speed' or 'constant acceleration' (is a limitation of the model) Must be a limitation of the model, so friction or air resistance or size of train is B0. **N.B.** Ignore incorrect **reasons** following a correct answer.		
		(1)	
			(8 marks)

Video solution:

AS Level maths June 2022 Question 2 Paper 22 Edexcel

November 2021 question 1

1. At time $t = 0$, a small stone is thrown vertically upwards with speed $14.7\,\text{m s}^{-1}$ from a point A.

At time $t = T$ seconds, the stone passes through A, moving downwards.

The stone is modelled as a particle moving freely under gravity throughout its motion.

Using the model,

(a) find the value of T,

(2)

(b) find the total distance travelled by the stone in the first 4 seconds of its motion.

(4)

(c) State one refinement that could be made to the model, apart from air resistance, that would make the model more realistic.

(1)

Arancha Ruiz

ANSWER

Question	Scheme	Marks	AOs
1.(a)	$14.7=-14.7+9.8T$ or $0=14.7T-\frac{1}{2}\times 9.8T^2$ or $0=14.7-9.8\times\left(\frac{1}{2}T\right)$ oe	M1	3.4
	$T=3$	A1	1.1b
		(2)	
(b)	$s_1=\frac{(14.7+0)}{2}\times 1.5$ $(11.025$ or $\frac{441}{40})$	M1	1.1b
	$s_2=\frac{1}{2}\times 9.8\times 2.5^2$ $(30.625$ or $\frac{245}{8})$ **OR** $s_3=14.7\times 1+\frac{1}{2}\times 9.8\times 1^2$ $(19.6$ or $\frac{98}{5})$ **OR** $-s_3=14.7\times 4-\frac{1}{2}\times 9.8\times 4^2$ (- 19.6) (allow omission of – on LHS)	M1	1.1b
	Total distance = s_1+s_2 **OR** $2s_1+s_3$	M1	2.1
	$=41.7$ m or 42 m	A1	1.1b
		(4)	
(c)	e.g. Take account of the dimensions of the stone (e.g. allow for spin), do not model the stone as a particle, use a more accurate value for g	B1	3.5c
		(1)	
			(7 marks)

Video solution:

https://youtu.be/lhJUDt77DGk

November 2020 question 1

1. At time $t = 0$, a small ball is projected vertically upwards with speed $U\,\text{m s}^{-1}$ from a point A that is 16.8 m above horizontal ground.

The speed of the ball at the instant immediately before it hits the ground for the first time is $19\,\text{m s}^{-1}$

The ball hits the ground for the first time at time $t = T$ seconds.

The motion of the ball, from the instant it is projected until the instant just before it hits the ground for the first time, is modelled as that of a particle moving freely under gravity.

The acceleration due to gravity is modelled as having magnitude $10\,\text{m s}^{-2}$

Using the model,

(a) show that $U = 5$

(2)

(b) find the value of T,

(2)

(c) find the time from the instant the ball is projected until the instant when the ball is 1.2 m below A.

(4)

(d) Sketch a velocity-time graph for the motion of the ball for $0 \leqslant t \leqslant T$, stating the coordinates of the start point and the end point of your graph.

(2)

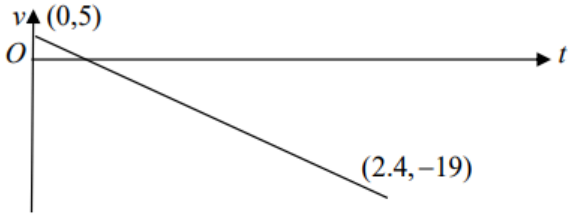
In a refinement of the model of the motion of the ball, the effect of air resistance on the ball is included and this refined model is now used to find the value of U.

(e) State, with a reason, how this new value of U would compare with the value found in part (a), using the initial unrefined model.

(1)

ANSWER

Question	Scheme	Marks	AOs
1.(a)	$19^2 = (-U)^2 + 2\times10\times16.8$ (Allow use of $g = 9.8$ for this M mark)	M1	2.1
	$U = 5$ *	A1*	1.1b
		(2)	
	For consistent use of $g = 9.8$ in parts (b), (c) and (d), treat as a MR. i.e. max (b) M1A0 (c)M1A0M(A)0A1ft (d)B1B1ft		
(b)	$19 = -5 + 10T$ **OR** $16.8 = \frac{(-5+19)}{2}T$ **OR** $16.8 = -5T + \frac{1}{2}\times10T^2$ **OR** $16.8 = 19T - \frac{1}{2}\times10T^2$	M1	2.1
	$T = 2.4$	A1	1.1b
		(2)	
(c)	$1.2 = -5t + \frac{1}{2}\times10\times t^2$	M1	2.1
	$5t^2 - 5t - 1.2 = 0$	A1	1.1b
		M(A)1	1.1b
	$t = 1.2$ (s)	A1	1.1b
		(4)	

(d)		B1 shape	1.1b
	(0,5) and (2.4, −19) Allow these to be marked on the axes.	B1ft	1.1b
		(2)	
(e)	Greater since air resistance would slow the ball down.	B1	3.5a
		(1)	
(f)	Take into account: spin, wind effects, use a more accurate value of g, not model the ball as a particle	B1	3.5c
		(1)	

Video solution:

https://youtu.be/Q6kj7RPTczU

June 2019 question 1

1. At time $t = 0$, a parachutist falls vertically from rest from a helicopter which is hovering at a height of 550 m above horizontal ground.

The parachutist, who is modelled as a particle, falls for 3 seconds before her parachute opens.

While she is falling, and before her parachute opens, she is modelled as falling freely under gravity.

The acceleration due to gravity is modelled as being $10\,\text{m}\,\text{s}^{-2}$.

(a) Using this model, find the speed of the parachutist at the instant her parachute opens.

(1)

When her parachute is open, the parachutist continues to fall vertically.

Immediately after her parachute opens, she decelerates at $12\,\text{m}\,\text{s}^{-2}$ for 2 seconds before reaching a constant speed and she reaches the ground with this speed.

The total time taken by the parachutist to fall the 550 m from the helicopter to the ground is T seconds.

(b) Sketch a speed-time graph for the motion of the parachutist for $0 \leqslant t \leqslant T$.

(2)

(c) Find, to the nearest whole number, the value of T.

(5)

In a refinement of the model of the motion of the parachutist, the effect of air resistance is included before her parachute opens and this refined model is now used to find a new value of T.

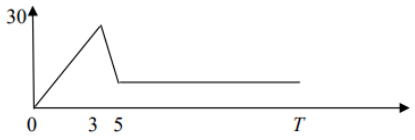
(d) How would this new value of T compare with the value found, using the initial model, in part (c)?

(1)

(e) Suggest one further refinement to the model, apart from air resistance, to make the model more realistic.

(1)

ANSWER

Question	Scheme	Marks	AOs	Notes
1 (a)	$V = 30\ (\text{m s}^{-1})$	B1	3.4	cao
		(1)		
(b)	 shape figs	B1	1.1b	Overall shape of the graph, starting at the origin. Dotted vertical line at end is OK but solid vertical line is B0
		B1**ft**	1.1b	3, 5 and T marked on the t-axis, and **ft** on their 30 marked on the speed axis. 3 must be where graph reaches a peak. Allow delineators: 3, 2 and $T - 5$ or a mixture
		(2)		
(c)	Using total area = 550 to set up an equation in **one unknown,** Or they may use *suvat* on one or more of the sections (but must still be considering all sections) M0 if they use one *suvat* equation for the whole motion	M1	2.1	Need all sections to be included, with correct structure for each section. e.g. triangle + trapezium + rectangle oe = 550 to give an equation in **one unknown (may not be *T*)**
	$\frac{1}{2}\times 3\times 30+\frac{(30+6)}{2}\times 2+6(T-5)=550$ **OR:** $\frac{1}{2}\times 3\times 30+\frac{1}{2}\times 2\times 24+6(T-3)=550$ **OR:** $\frac{1}{2}\times 3\times 30+\frac{1}{2}\times 2\times 24+(2\times 6)+6(T-5)=550$	A2 **ft**	1.1b	**ft** on their answer to (a). -1 each error. **N.B.** If '6' is incorrect, treat as one error, unless it is correct ft from their 30.

	Solve for T	M1	1.1b	Attempt to solve for T provided they have tried to find the area using at least 3 sections. (M0 if they only solve for their unknown and never try to find T)
	$T = 83$ (nearest whole number)	A1	1.1b	83 is the only answer
		(5)		
(d)	New value of T would be bigger (ignore their reasons whether correct or not)	B1	3.5a	Clear statement about the value of T Allow '*it* would increase, get larger etc' B0 for 'Takes longer' or 'the value of T would be longer'
		(1)		
(e)	e.g. effect of wind; allow for dimensions of parachutist; use a more accurate value for g; parachutist does not fall vertically after chute opens; smooth changes in v; time for parachute to open; deceleration not constant (but B0 if they say *acceleration* not constant); smooth changes in a; B0 for: moves horizontally; mass/weight of parachutist; upthrust; air pressure;air resistance; terminal velocity	B1	3.5c	Any appropriate refinement of the model. B0 if incorrect (or irrelevant) extras
		(1)		
		(10 marks)		

June 2018 Question 6

6. A man throws a tennis ball into the air so that, at the instant when the ball leaves his hand, the ball is 2 m above the ground and is moving vertically upwards with speed $9\,\text{m s}^{-1}$

The motion of the ball is modelled as that of a particle moving freely under gravity and the acceleration due to gravity is modelled as being of constant magnitude $10\,\text{m s}^{-2}$

The ball hits the ground T seconds after leaving the man's hand.

Using the model, find the value of T.

(4)

ANSWER

Question	Scheme	Marks	AOs
6.	Equation in t only	M1	2.1
	$-2 = 9t - \frac{1}{2} \times 10t^2$	A1	1.1b
	$5t^2 - 9t - 2 = 0 = (5t+1)(t-2)$	DM1	1.1b
	$T = 2$ (only)	A1	1.1b
		(4)	
			(4 marks)

June 2018 Question 7

7. A train travels along a straight horizontal track between two stations, A and B.

In a model of the motion, the train starts from rest at A and moves with constant acceleration $0.3\,\text{m s}^{-2}$ for 80 s.
The train then moves at constant velocity before it moves with a constant deceleration of $0.5\,\text{m s}^{-2}$, coming to rest at B.

(a) For this model of the motion of the train between A and B,

(i) state the value of the constant velocity of the train,

(ii) state the time for which the train is decelerating,

(iii) sketch a velocity-time graph.

(3)

The total distance between the two stations is 4800 m.

(b) Using the model, find the total time taken by the train to travel from A to B.

(3)

(c) Suggest one improvement that could be made to the model of the motion of the train from A to B in order to make the model more realistic.

(1)

ANSWER

Question	Scheme	Marks	AOs
7(a) (i)	24 ($m\,s^{-1}$)	B1	1.1b
(ii)	48 (s)	B1	1.1b
(iii)	 shape	B1	1.1b
		(3)	
(b)	Equating area under graph to 4800 to give equation in one unknown	M1	3.1b
	$\frac{1}{2}(T+T+80+48)\leftarrow 24=4800$ **OR** $(\frac{1}{2}\times 80\times 24)+24T+(\frac{1}{2}\times 48\times 24)=4800$ **oe**	A1**ft**	1.1b
	$T=136$ so total time is 264 (s)	A1	1.1b
		(3)	
(c)	Accept **Either**: a smooth change from acceleration to constant velocity or from constant velocity to deceleration. **Or** have train accelerating and/or decelerating at a variable rate Do not accept e.g. Comments on air resistance or resistive forces, straightness of track, horizontal track, friction, length of train, mass of train, not having train moving with constant velocity. B0 if either an incorrect extra is included or an incorrect reason for a valid improvement is included. N.B. Variable acceleration due to air resistance is B0 **BUT** Variable acceleration due to **variable** air resistance is B1	B1	3.5c
		(1)	
			(7 marks)

Ch. 10: Forces and Motion

June 2024 Question 4

4.

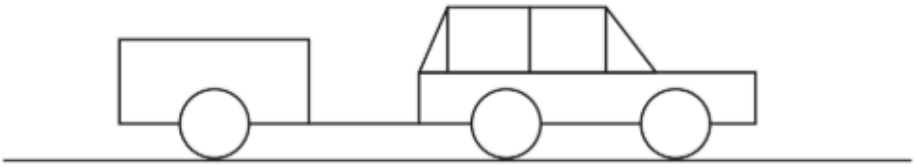


Figure 2

Figure 2 shows a car towing a trailer along a straight horizontal road.

The mass of the car is 800 kg and the mass of the trailer is 600 kg.

The trailer is attached to the car by a towbar which is parallel to the road and parallel to the direction of motion of the car and the trailer.

The towbar is modelled as a light rod.

The resistance to the motion of the car is modelled as a constant force of magnitude 400 N.

The resistance to the motion of the trailer is modelled as a constant force of magnitude R newtons.

The engine of the car is producing a constant driving force that is horizontal and of magnitude 1740 N.

The acceleration of the car is $0.6\,\text{m s}^{-2}$ and the tension in the towbar is T newtons.

Using the model,

(a) show that $R = 500$

(3)

(b) find the value of T.

(3)

At the instant when the speed of the car and the trailer is $12.5\ \text{m s}^{-1}$, the towbar breaks.

The trailer moves a further distance d metres before coming to rest.

The resistance to the motion of the trailer is modelled as a constant force of magnitude 500 N.

Using the model,

(c) show that, after the towbar breaks, the deceleration of the trailer is $\frac{5}{6}\,\text{m s}^{-2}$

(1)

(d) find the value of d.

(3)

In reality, the distance d metres is likely to be different from the answer found in part (d).

(e) Give two **different** reasons why this is the case.

(2)

ANSWER

Question	Scheme	Marks	AOs
	N.B. Use the mass in the *ma* term to determine which part of the system the equation refers to.		
4(a)	Equation of motion:	M1	3.3
	$1740-400-R=(600+800)\times 0.6$ Or $\begin{cases}1740-T-400=800\times 0.6\\ T-R=600\times 0.6\end{cases}$ with T eliminated or found (860) from the first equation, and then used in the second to find R.	A1	1.1b
	$R=1740-840-400=500$ *	A1*	2.2a
		(3)	
(b)	Equation of motion for car or trailer	M1	3.4
	$1740-T-400=800\times 0.6$ or $T-500=600\times 0.6$	A1	1.1b
	$T=860$	A1	1.1b
		(3)	

(c)	Use of $500 = \pm 600a$ to obtain * **N.B.** Need to see explicitly deceleration $= \frac{5}{6}$	B1*	1.1b
		(1)	
(d)	Complete method to find distance with $a = \pm\frac{5}{6}$	M1	3.4
	$0 = 12.5^2 - 2\times\frac{5}{6}\times d$ **OR e.g.** $t = \frac{12.5}{\frac{5}{6}} = 15$ then $d = \frac{1}{2}\times\frac{5}{6}\times 15^2$ or $d = \frac{1}{2}\times(0+12.5)\times 15$ or $d = 12.5\times 15 + \frac{1}{2}\times(-\frac{5}{6})\times 15^2$	A1	1.1b
	93.75 oe	A1	1.1b
		(3)	
(e)	**N.B.** If **more than two** answers given, subtract 1 from any marks earned for each incorrect extra answer which are in group 7 below but do **not** penalise answers which are in group 8 and then, on ePEN, award as appropriate either: B1B1, B1B0 or B0B0 but NOT B0B1.	B1 B1	3.5b 3.5b
		(2)	
			(12 marks)

June 2024 Question 3

3. [*In this question,* **i** *and* **j** *are perpendicular unit vectors in a horizontal plane.*]

A particle P is moving on a smooth horizontal surface under the action of two forces.

Given that

- the mass of P is 2 kg
- the two forces are $(2\mathbf{i} + 4\mathbf{j})$N and $(c\mathbf{i} - 2\mathbf{j})$N, where c is a constant
- the magnitude of the acceleration of P is $\sqrt{5}\,\text{m s}^{-2}$

find the two possible values of c.

(5)

ANSWER

Question	Scheme	Marks	AOs
3	Resultant force $=(2+c)\mathbf{i}+(4-2)\mathbf{j}$	B1	1.1b
	$\sqrt{(2+c)^2+2^2}$ or $(2+c)^2+2^2$	M1	3.1a
	$(2+c)^2+4=4\times5$ or $\sqrt{(2+c)^2+2^2}=2\times\sqrt{5}$	M1	3.1a
	OR		
	$\mathbf{a}=\frac{1}{2}\left[(2+c)\mathbf{i}+(4-2)\mathbf{j}\right]$ oe	M1	
	$\frac{1}{4}\left[(2+c)^2+4\right]=5$ or $\frac{1}{2}\sqrt{(2+c)^2+2^2}=\sqrt{5}$	M1	
	$c=2$ or $c=-6$	A1	1.1b
	$c=2$ and $c=-6$	A1	2.2a
		(5)	
			(5 marks)

June 2023 Question 4

4.

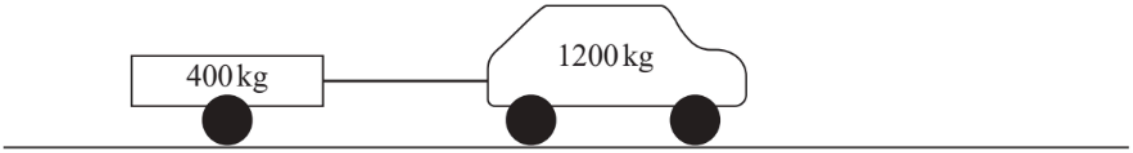


Figure 2

A car of mass 1200 kg is towing a trailer of mass 400 kg along a straight horizontal road using a tow rope, as shown in Figure 2.
The rope is horizontal and parallel to the direction of motion of the car.

- The resistance to motion of the car is modelled as a constant force of magnitude $2R$ newtons
- The resistance to motion of the trailer is modelled as a constant force of magnitude R newtons
- The rope is modelled as being light and inextensible
- The acceleration of the car is modelled as $a\,\text{m s}^{-2}$

The driving force of the engine of the car is 7400 N and the tension in the tow rope is 2400 N.

Using the model,
(a) find the value of a

(5)

In a refined model, the rope is modelled as having mass and the acceleration of the car is found to be $a_1\,\text{m s}^{-2}$

(b) State how the value of a_1 compares with the value of a

(1)

(c) State one limitation of the model used for the resistance to motion of the car.

(1)

ANSWER

Question	Scheme	Marks	AOs
4(a)	Equation of motion for the car	M1	3.3
	$7400 - 2R - 2400 = 1200a$	A1	1.1b
	Equation of motion for the trailer	M1	3.4
	$2400 - R = 400a$	A1	1.1b
	$a = 0.5$	A1	1.1b
		(5)	
	N.B. Either equation could be replaced by: Equation of motion for the whole system $7400 - 3R = 1600a$		
4(b)	The value of a_1 would be less than the value of a. Allow 'a_1 would be slower than a', **N.B.** Allow 'it would be less than a'	B1	3.5a
		(1)	
4(c)	The resistance won't be constant or just 'it won't be constant.' Allow the negative also: The resistance is constant or just 'it is constant' B0 for 'it doesn't take account of air resistance'	B1	3.5b
		(1)	
			(7 marks)

June 2022 Question 4

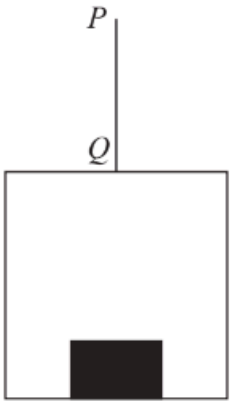


Figure 1

A vertical rope PQ has its end Q attached to the top of a small lift cage.

The lift cage has mass 40 kg and carries a block of mass 10 kg, as shown in Figure 1.

The lift cage is raised vertically by moving the end P of the rope vertically upwards with constant acceleration $0.2\,\text{m s}^{-2}$

The rope is modelled as being light and inextensible and air resistance is ignored.

Using the model,

(a) find the tension in the rope PQ

(3)

(b) find the magnitude of the force exerted on the block by the lift cage.

(3)

ANSWER

Question	Scheme	Marks	AOs
	N.B. Use the mass in the '*ma*' term of an equation to determine which part of the system (cage and block, cage or block) it applies to.		
4(a)	Translate situation into the model and set up the **equation** of motion for the cage and the block to obtain an equation in T only.	M1	3.3
	$T-40g-10g=50\times0.2$	A1	1.1b
	500 (N) Must be positive	A1	1.1b
	Some examples: $T-50=50\times0.2$ and $T-40g-10g=50g\times0.2$ both score M1A0A0		
		(3)	
(b)	Use the model to set up the equation of motion for the block to obtain an equation in R only.	M1	3.4
	$R-10g=10\times0.2$ Allow $-R$ instead of R	A1	1.1b
	100 (N) Must be positive.	A1	1.1b
	OR: Use the model to set up the equation of motion for the cage to obtain an equation in R only.	M1	3.4
	$T-40g-R=40\times0.2$ with their T substituted	A1	1.1b
	100 (N) Must be positive	A1	1.1b
		(3)	

Video solution:

https://youtu.be/RXP38AEYsw8

November 2021 question 3

3.

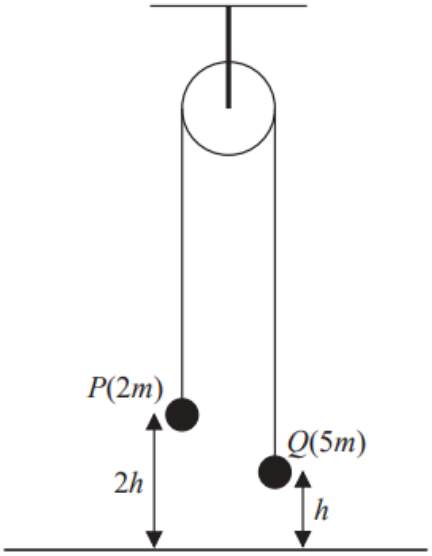


Figure 1

A ball P of mass $2m$ is attached to one end of a string.

The other end of the string is attached to a ball Q of mass $5m$.

The string passes over a fixed pulley.

The system is held at rest with the balls hanging freely and the string taut.

The hanging parts of the string are vertical with P at a height $2h$ above horizontal ground and with Q at a height h above the ground, as shown in Figure 1.

The system is released from rest.

In the subsequent motion, Q does not rebound when it hits the ground and P does not hit the pulley.

The balls are modelled as particles.

The string is modelled as being light and inextensible.

The pulley is modelled as being small and smooth.

Continues in next page

Air resistance is modelled as being negligible.

Using this model,

(a) (i) write down an equation of motion for P,

(ii) write down an equation of motion for Q,

(4)

(b) find, in terms of h only, the height above the ground at which P first comes to instantaneous rest.

(7)

(c) State one limitation of modelling the balls as particles that could affect your answer to part (b).

(1)

In reality, the string will not be inextensible.

(d) State how this would affect the accelerations of the particles.

(1)

ANSWER

Question	Scheme	Marks	AOs
3(a)	(i) Equation of motion for P	M1	3.3
	$T-2mg=2ma$	A1	1.1b
	(ii) Equation of motion for Q	M1	3.3
	$5mg-T=5ma$	A1	1.1b
	N.B. (allow $(-a)$ in both equations)	**(4)**	
3(b)	Solve equations for a or use whole system equation and solve for a	M1	3.4
	$a=\frac{3g}{7}=4.2$	A1	1.1b
	$v=\sqrt{2\times\frac{3g}{7}\times h}=\sqrt{8.4h}$ or $v^2=2\times\frac{3g}{7}\times h\ (=8.4h)$	M1	1.1b
	$0=\frac{6gh}{7}-2gH$	M1	1.1b
	$H=\frac{3h}{7}$	A1	1.1b
	Total height $=2h+h+H$	M1	2.1
	Total height $=\frac{24h}{7}$	A1	1.1b
		(7)	
3(c)	e.g. The distance that Q falls to the ground would not be exactly h oe	B1	3.5b
		(1)	
3(d)	e.g. The accelerations of the balls would not have equal magnitude (allow 'wouldn't be the same' oe) B0 if they say 'inextensible => acceleration same'	B1	3.5a
		(1)	
			(13 marks)

Video solution:

A-Level maths November 2021 Question 3 mechanics Paper 22 Edexcel

November 2020 question 2

2.

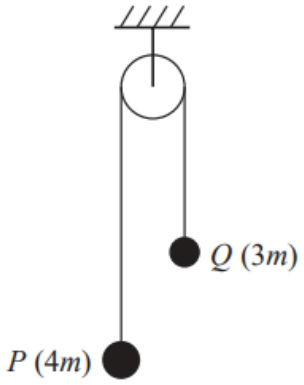


Figure 1

One end of a string is attached to a small ball P of mass $4m$.

The other end of the string is attached to another small ball Q of mass $3m$.

The string passes over a fixed pulley.

Ball P is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 1.

Ball P is released.

The string is modelled as being light and inextensible, the balls are modelled as particles, the pulley is modelled as being smooth and air resistance is ignored.

(a) Using the model, find, in terms of m and g, the magnitude of the force exerted on the pulley by the string while P is falling and before Q hits the pulley.

(8)

(b) State one limitation of the model, apart from ignoring air resistance, that will affect the accuracy of your answer to part (a).

(1)

ANSWER

Question	Scheme	Marks	AOs
2(a)	Equation of motion for P with usual rules	M1	3.3
	$4mg - T = 4ma$	A1	1.1b
	Equation of motion for Q with usual rules	M1	3.3
	$T - 3mg = 3ma$	A1	1.1b
	Solve these equations for T (does not need to be in terms of mg)	M1	1.1b
	$T = \frac{24mg}{7}$ in any form (does not need to be a single term)	A1	1.1b
	Force on pulley $= 2T$	M1	3.4
	$\frac{48mg}{7}$ Accept $6.9mg$ or better	A1	1.1b
		(8)	
2(b)	Weight of the rope or extensibility of rope Or: pulley may not be smooth	B1	3.5b
		(1)	
			(9 marks)

Video solution:

Mechanics Year 1 May 2020 Question 2

June 2019 question 2

2.

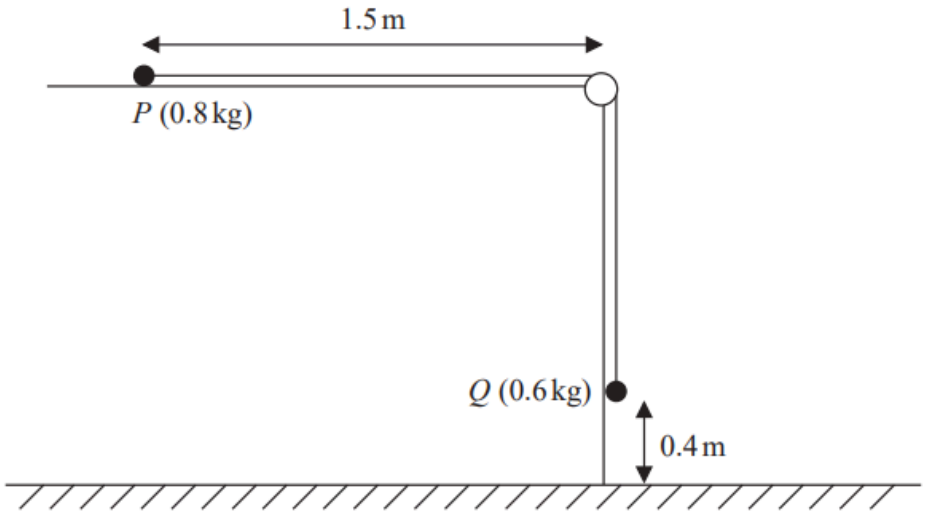


Figure 1

A small ball, P, of mass 0.8 kg, is held at rest on a smooth horizontal table and is attached to one end of a thin rope.

The rope passes over a pulley that is fixed at the edge of the table.

The other end of the rope is attached to another small ball, Q, of mass 0.6 kg, that hangs freely below the pulley.

Ball P is released from rest, with the rope taut, with P at a distance of 1.5 m from the pulley and with Q at a height of 0.4 m above the horizontal floor, as shown in Figure 1.

Ball Q descends, hits the floor and does not rebound.

The balls are modelled as particles, the rope as a light and inextensible string and the pulley as small and smooth.

Using this model,

(a) show that the acceleration of Q, as it falls, is $4.2\,\text{m s}^{-2}$

(5)

(b) find the time taken by P to hit the pulley from the instant when P is released.

(6)

(c) State one limitation of the model that will affect the accuracy of your answer to part (a).

(1)

ANSWER

Question	Scheme	Marks	AOs	Notes
2(a)	Equation of motion for Q	M1	3.3	Equation of motion for Q with correct no. of terms, condone sign errors.
	$0.6g - T = 0.6a$	A1	1.1b	A correct equation
	Equation of motion for P	M1	3.3	Equation of motion for Q with correct no. of terms, condone sign errors.
	$T = 0.8a$	A1	1.1b	A correct equation
	$a = 4.2$ (m s^{-2}) *	A1*	2.2a	Given acceleration obtained correctly. **You must see an equation in a only before reaching $a = 4.2$**
		(5)		**N.B.** if they just use the whole system equation: $0.6g = 1.4a$, can only score max M1A1M0A0A0 **N.B.** Use of $g = 9.81$ or 10 loses final A mark only. **N.B.** Complete verification, using both equations, can score full marks.
(b)	$0.4 = \frac{1}{2} \times 4.2 \times t_1^2$ or e.g. they may find v first and then use $v = 4.2t_1$	M1	2.1	Complete method (they may use more than one *suvat* equation) to find time for Q to hit the floor (M0 if 0.4 **not** used as distance moved and/or if 4.2 is **not** used as acceleration and this applies to finding v as well if they use v to find t_1)
	$t_1 = 0.436(4357\ldots..)$ Allow 0.43, 0.44, 0.436, or better, or any surd form e.g. $\frac{2}{\sqrt{21}}$	A1	1.1b	See alternatives
	$v = 4.2 \times t_1$ or $v = \sqrt{2 \times 4.2 \times 0.4}$ or $0.4 = \frac{(0+v)}{2} \times t_1$ $(v = 1.8330\ldots)$	M1	3.4	Complete method to find speed of Q as it hits the floor (M0 if 0.4 **not** used as distance moved and/or if 4.2 is **not** used as acceleration and this applies to finding t_1 as well if they use t_1 to find v)
	$t_2 = \frac{1.5 - 0.4}{v}$	M1	1.1b	Uses distance/speed to find time for P to hit the pulley after Q has hit the floor. N.B. This is independent of previous M mark.
	Complete strategy to solve the problem by finding the sum of the two times $t_1 + t_2$	**DM1**	3.1b	Complete method to solve the problem by finding and adding the two required times, dependent on previous three M marks
	1.0 (s) or 1.04 (s)	A1	1.1b	
		(6)		
(c)	e.g. rope being light; rope being inextensible; pulley being smooth; pulley being small; balls being particles	B1	3.5b	Clear statement. Allow negatives of these i.e. the rope may not be light, the rope may not be inextensible etc Must be a limitation of the model stated in the question Penalise incorrect or irrelevant extras
		(1)		B0 for: Air resistance, table being smooth
		(12 marks)		

Video solution:

A Level maths June 2019 Question 2 Mechanics paper 22 Edexcel

June 2018 Question 9

9.

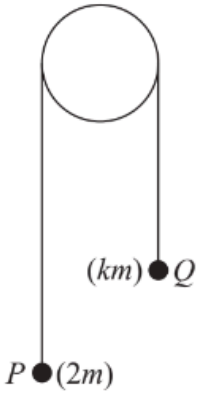


Figure 1

Two small balls, P and Q, have masses $2m$ and km respectively, where $k < 2$.
The balls are attached to the ends of a string that passes over a fixed pulley.
The system is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 1.

The system is released from rest and, in the subsequent motion, P moves downwards with an acceleration of magnitude $\frac{5g}{7}$

The balls are modelled as particles moving freely.
The string is modelled as being light and inextensible.
The pulley is modelled as being small and smooth.

Using the model,

(a) find, in terms of m and g, the tension in the string,

(3)

(b) explain why the acceleration of Q also has magnitude $\frac{5g}{7}$

(1)

(c) find the value of k.

(4)

(d) Identify one limitation of the model that will affect the accuracy of your answer to part (c).

(1)

ANSWER

Question	Scheme	Marks	AOs
9(a)	Equation of motion for P	M1	3.3
	$2mg - T = 2m \leftrightarrow \frac{5g}{7}$	A1	1.1b
	$T = \frac{4mg}{7}$	A1	1.1b
		(3)	
(b)	Since the string is modelled as being inextensible	B1	3.4
		(1)	
(c)	Equation of motion for Q **OR** for whole system	M1	3.3
	$T - kmg = km \leftrightarrow \frac{5g}{7}$ **OR** $2mg - kmg = (km + 2m)\frac{5g}{7}$	A1	1.1b
	$\frac{4mg}{7} - kmg = km \leftrightarrow \frac{5g}{7}$ oe and solve for k	DM1	1.1b
	$k = \frac{1}{3}$ or 0.333 or better	A1	1.1b
		(4)	
(d)	e.g The model does not take account of the mass of the string (see notes below for alternatives)	B1	3.5b
		(1)	
			(9 marks)

Ch. 11: Variable Acceleration

June 2024 Question 2

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

Solutions relying on calculator technology are not acceptable.

A particle is moving along a straight line.

At time t seconds, $t > 0$, the velocity of the particle is $v\,\text{m s}^{-1}$, where

$$v = 2t - 7\sqrt{t} + 6$$

(a) Find the acceleration of the particle when $t = 4$

(3)

When $t = 1$ the particle is at the point X.

When $t = 2$ the particle is at the point Y.

Given that the particle does not come to instantaneous rest in the interval $1 < t < 2$

(b) show that $XY = \frac{1}{3}\left(41 - 28\sqrt{2}\right)$ metres.

(4)

ANSWER

Question	Scheme	Marks	AOs
2(a)	Differentiate $2t-7\sqrt{t}+6$ wrt t	M1	3.1a
	$2-\frac{7}{2\sqrt{t}}$ oe	A1	1.1b
	When $t=4$, $a=0.25(\text{ms}^{-2})$	A1	1.1b
		(3)	
(b)	Integrate $2t-7\sqrt{t}+6$ wrt t	M1	3.1a
	$t^2-\frac{14}{3}t^{\frac{3}{2}}+6t(+C)$	A1	1.1b
	Use the limits to find XY	DM1	1.1b
	$(XY=)\ \frac{1}{3}\left(41-28\sqrt{2}\right)$ (metres) *	A1*	1.1b
		(4)	
			(7 marks)

June 2023 Question 3

3. **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, $v\,\text{m s}^{-1}$, 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)

ANSWER

Question	Scheme	Marks	AOs
3(a)	$15-3^2-2\times3=0$ *	B1*	1.1b
		(1)	
3(b)	Differentiate *v* wrt *t*	M1	2.1
	$-2t-2$	A1	1.1b
	$8\,(\text{m s}^{-2})$	A1	1.1b
		(3)	

3(b)	Differentiate *v* wrt *t*	M1	2.1
	$-2t-2$	A1	1.1b
	$8\,(\text{m s}^{-2})$	A1	1.1b
		(3)	
3(c)	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)

June 2022 Question 3

3. A fixed point O lies on a straight line.

A particle P moves along the straight line.

At time t seconds, $t \geqslant 0$, the distance, s metres, of P from O is given by

$$s = \frac{1}{3}t^3 - \frac{5}{2}t^2 + 6t$$

(a) Find the acceleration of P at each of the times when P is at instantaneous rest.

(6)

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

(3)

ANSWER

Question	Scheme	Marks	AOs
3(a)	Differentiate s wrt t	M1	3.1a
	$(v=)\ t^2-5t+6$	A1	1.1b
	Equate their v to 0 and solve	M1	1.1b
	$t=2$ or 3	A1	1.1b
	$(a=)\ 2t-5$	B1**ft**	2.1
	$a=$ 1 and -1 (m s^{-2}) isw (A0 if extras)	A1	1.1b
		(6)	
(b)	Attempt to find values of s for $t=2$, 3 *and* 4 oe Correct values are $\left(s_2=\frac{14}{3}, s_3=\frac{9}{2}\ \textit{and}\ s_4=\frac{16}{3}\right)$ Could be implied by correct values for: s_2 , (s_3-s_2) and (s_4-s_3) which are $\frac{14}{3}$, $(-\frac{1}{6})$ and $\frac{5}{6}$	**DM1**	1.1b
	Total distance travelled $= s_2+(s_2-s_3)+s_4-s_3$ **OR** $s_2-(s_3-s_2)+s_4-s_3$ **OR** $\left[\frac{1}{3}t^3-\frac{5}{2}t^2+6t\right]_0^2-\left[\frac{1}{3}t^3-\frac{5}{2}t^2+6t\right]_2^3+\left[\frac{1}{3}t^3-\frac{5}{2}t^2+6t\right]_3^4$ **OR** $\frac{14}{3}-(-\frac{1}{6})+\frac{5}{6}$ **OR** $s_2+2(s_2-s_3)+s_4-s_2$ $(=2s_2-2s_3+s_4)$ oe	M1	2.1
	$5\frac{2}{3}$ oe (m) Accept 5.7 or better	A1	1.1b
		(3)	
			(9 marks)

Video solution:

https://youtu.be/RXP38AEYsw8

November 2021 question 2

2. A particle P moves along a straight line.

At time t seconds, the velocity $v\,\text{m s}^{-1}$ of P is modelled as

$$v = 10t - t^2 - k \qquad t \geqslant 0$$

where k is a constant.

(a) Find the acceleration of P at time t seconds.

(2)

The particle P is instantaneously at rest when $t = 6$

(b) Find the other value of t when P is instantaneously at rest.

(4)

(c) Find the total distance travelled by P in the interval $0 \leqslant t \leqslant 6$

(4)

ANSWER

Question	Scheme	Marks	AOs
2(a)	Differentiate v w.r.t. t	M1	3.1a
	$a=\frac{\mathrm{d}v}{\mathrm{d}t}=10-2t$ isw	A1	1.1b
		(2)	
2(b)	Solve problem using $v=0$ when $t=6$	M1	3.1a
	$0=10t-t^2-24$	A1	1.1b
	Solve quadratic oe to find other value of t	M1	1.1b
	$t=4$	A1	1.1b
		(4)	
2(c)	Integrate v or $-v$ w.r.t. t	M1	3.1a
	$5t^2-\frac{1}{3}t^3-24t$	A1	1.1b
	Total distance $=-\left[5t^2-\frac{1}{3}t^3-24t\right]_0^4+\left[5t^2-\frac{1}{3}t^3-24t\right]_4^6$	M1	2.1
	$\frac{116}{3}$ (m)	A1	1.1b
		(4)	
			(10 marks)

November 2020 question 3

3. A particle P moves along a straight line such that at time t seconds, $t \geqslant 0$, after leaving the point O on the line, the velocity, $v\,\text{m s}^{-1}$, of P is modelled as

$$v = (7 - 2t)(t + 2)$$

(a) Find the value of t at the instant when P stops accelerating.

(4)

(b) Find the distance of P from O at the instant when P changes its direction of motion.

(5)

In this question, solutions relying on calculator technology are not acceptable.

ANSWER

Question	Scheme	Marks	AOs
3(a)	$v = 3t - 2t^2 + 14$ and differentiate	M1	3.1a
	$a = \frac{dv}{dt} = 3 - 4t$ or $(7 - 2t) - 2(t + 2)$ using product rule	A1	1.1b
	$3 - 4t = 0$ and solve for t	M1	1.1b
	$t = \frac{3}{4}$ oe	A1	1.1b
		(4)	
3(b)	Solve problem using $v = 0$ to find a value of t $\left(t = \frac{7}{2}\right)$	M1	3.1a
	$v = 3t - 2t^2 + 14$ and integrate	M1	1.1b
	$s = \frac{3t^2}{2} - \frac{2t^3}{3} + 14t$	A1	1.1b
	Substitute $t = \frac{7}{2}$ into their s expression (M0 if using *suvat*)	M1	1.1b
	$s = \frac{931}{24} = 38\frac{19}{24} = 38.79166..(\text{m})$ Accept 39 or better	A1	1.1b
		(5)	
			(9 marks)

Video solution:

https://youtu.be/BvgzBBXwnmU

June 2019 question 3

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

$$v = 12 + 4t - t^2$$

Find

(a) the magnitude of the acceleration of P when P is at instantaneous rest,

(5)

(b) the distance travelled by P in the interval $0 \leqslant t \leqslant 3$

(3)

ANSWER

Question	Scheme	Marks	AOs	Notes
3(a)	$v = 12 + 4t - t^2 = 0$ and solving	M1	3.1a	Equating v to 0 and solving the quadratic If no evidence of solving, and at least one answer wrong, M0
	$t = 6$ (or -2)	A1	1.1b	6 but allow -2 as well at this stage
	Differentiate v wrt t	M1	1.1a	For differentiation (both powers decreasing by 1)
	$(a = \frac{dv}{dt} =) \; 4 - 2t$	A1	1.1b	Cao; only need RHS
	When $t = 6$, $a = -8$; Magnitude is 8 (m s^{-2})	A1	1.1b	Substitute in $t = 6$ and get 8 (m s^{-2}) as the answer . Must be **positive.** (A0 if two answers given)
		(5)		
(b)	Integrate v wrt t	M1	3.1a	For integration (at least two powers increasing by 1)
	$(s =) 12t + 2t^2 - \frac{1}{3}t^3 (+C)$	A1	1.1b	Correct expression (ignore C) only need RHS Must be used in part (b)
	$t = 3$ => distance = 45 (m)	A1	1.1b	Correct distance. Ignore units
		(3)		
		(8 marks)		

June 2018 Question 8

8. A particle, P, moves along the x-axis. At time t seconds, $t \geqslant 0$, the displacement, x metres, of P from the origin O, is given by $x = \frac{1}{2}t^2(t^2 - 2t + 1)$

(a) Find the times when P is instantaneously at rest.

(5)

(b) Find the total distance travelled by P in the time interval $0 \leqslant t \leqslant 2$

(3)

(c) Show that P will never move along the negative x-axis.

(2)

ANSWER

Question	Scheme	Marks	AOs
8(a)	Multiply out and differentiate *wrt* to time (or use of product rule i.e. must have two terms with correct structure)	M1	1.1a
	$v=2t^3-3t^2+t$	A1	1.1b
	$2t^3-3t^2+t=0$ and solve: $t(2t-1)(t-1)=0$	**DM1**	1.1b
	$t=0$ or $t=\frac{1}{2}$ or $t=1$; any two	A1	1.1b
	All three	A1	1.1b
		(5)	
(b)	Find x when $t=0$, $\frac{1}{2}$, 1 and 2 : $(0, \frac{1}{32}, 0, 2)$	M1	2.1
	Distance $=\frac{1}{32}+\frac{1}{32}+2$	M1	2.1
	$2\frac{1}{16}$ (m) oe or 2.06 or better	A1	1.1b
		(3)	
(c)	$x=\frac{1}{2}t^2(t-1)^2$	M1	3.1a
	$\frac{1}{2}$ perfect square so $x \geq 0$ i.e. never negative	A1 cso	2.4
		(2)	
			(10 marks)