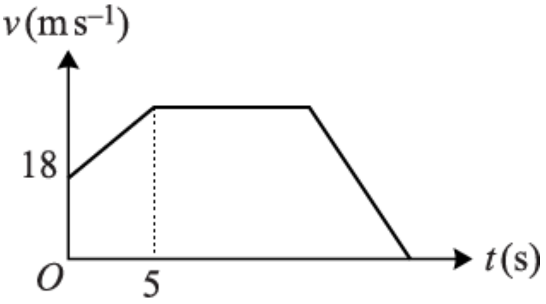
1.



The diagram shows the $(t,\ v)$ graph of a car moving along a straight road, where v m s^{-1} is the velocity of the car at time t s after it passes through the point A. The car passes through A with velocity 18 m s^{-1}, and moves with constant acceleration 2.4 m s^{-2} until $t = 5$. The car subsequently moves with constant velocity until it is 300 m from A. When the car is more than 300 m from A, it has constant deceleration 6 m s^{-2}, until it comes to rest.

i. Find the greatest speed of the car.

[2]

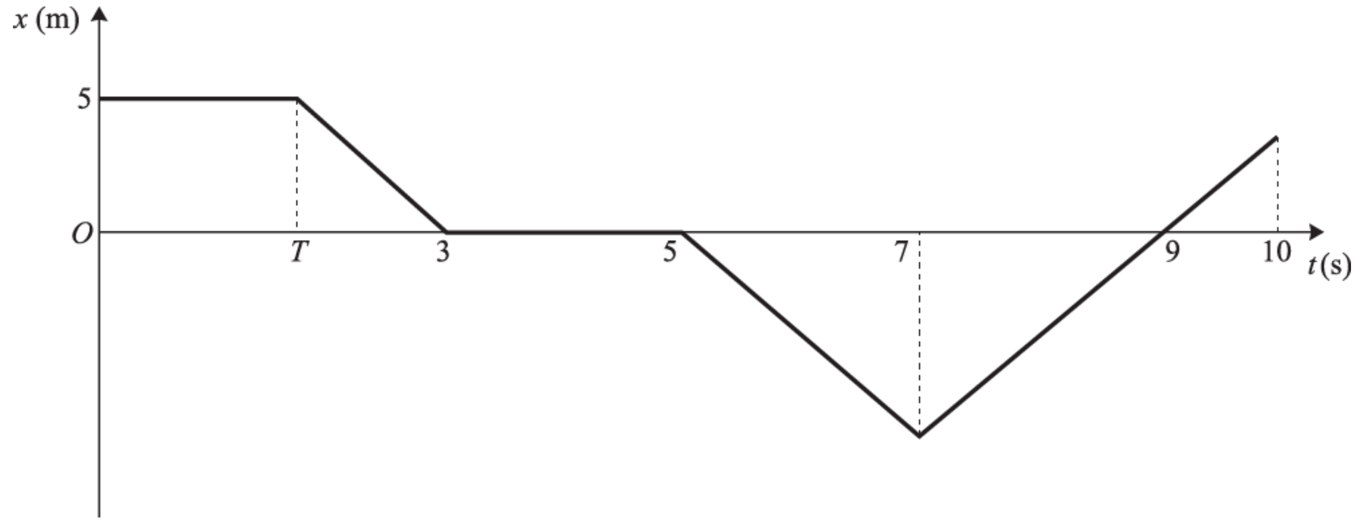
ii. Calculate the value of t for the instant when the car begins to decelerate.

[5]

iii. Calculate the distance from A of the car when it is at rest.

[3]

2.



A particle P can move in a straight line on a horizontal surface. At time t seconds the displacement of P from a fixed point A on the line is x m. The diagram shows the (t, x) graph for P. In the interval $0 \leqslant t \leqslant 10$, either the speed of P is 4 ms^{-1}, or P is at rest.

i. Show by calculation that $T = 1.75$.

[2]

ii. State the velocity of P when

a. $t = 2$,

[1]

b. $t = 8$,

[1]

c. $t = 9$.

[1]

iii. Calculate the distance travelled by P in the interval $0 \leqslant t \leqslant 10$.

[3]

For $t > 10$, the displacement of P from A is given by $x = 20t - t^2 - 96$.

iv. Calculate the value of t, where $t > 10$, for which the speed of P is 4 ms^{-1}.

[4]

3. A particle P is projected vertically downwards with initial speed 3.5 ms^{-1} from a point A which is 5 m above horizontal ground.

i. Find the speed of P immediately before it strikes the ground.

[2]

After striking the ground, P rebounds and moves vertically upwards and 0.87 s after leaving the ground P passes through A.

ii. Calculate the speed of P immediately after it leaves the ground.

[3]

It is given that the mass of P is 0.2 kg.

iii. Calculate the change in the momentum of P as a result of its collision with the ground.

[2]

4. A small ball is projected vertically upwards with speed 18 m s^{-1} from a point O on the ground. At the same instant a small object is released from rest at a point 27 m vertically above O.

(i) Verify that the ball and the object collide 1.5 s after they are set in motion. [4]

(ii) Find the velocities of the ball and the object immediately before they collide. [3]

The ball and the object have equal mass. When the ball and the object collide, they coalesce.

(iii) Find the time after their collision when they strike the ground at O. [5]

END OF QUESTION paper

Mark scheme

Question			Answer/Indicative content	Marks	Part marks and guidance	
1		i	$v = 18 + 2.4 \times 5$	M1	$v = u + at$	
		i	$v = 30$	A1		
		ii	Distance while accelerating = $(18 + 30) \times 5/2$	B1	Or $30 \times 5 - (30 - 18) \times 5/2$ etc = 120, or 45 + 75. Numerical.	
		ii	Distance at constant speed = $30(t - 5)$	B1	Tolerate $30t$. Algebraic.	
		ii		M1	Adds their areas to get 300	
		ii	$30(t - 5) + (18 + 30) \times 5/2 = 300$	A1	$30T = 300 - 120$, $30t + 45 + 75 = 300$, etc	
		ii	$t = 11$	A1		
		ii	*OR*			
		ii	Distance while accelerating = $(18 + 30) \times 5/2$ (= 120)	B1	Or $30 \times 5 - (30 - 18) \times 5/2$ etc = 120, or 45 + 75. Numerical.	
		ii	Distance at constant speed = 300 − cv(120)	M1	Subtracts their area from 300	
		ii	Time at constant speed = $\frac{(300 - \text{cv}(120))}{30}$	B1	Equivalent to "distance at constant speed algebraic"	
		ii	Time at constant speed = 6	A1		
		ii	$t = 11$	A1		
		ii	*OR*			
		ii	Distance = $30t$	B1	Rectangle, comprising 300 + area of "missing triangle"	
		ii	Distance = $(30 - 18) \times 5/2$	B1	"Missing triangle", to be removed	
		ii	$30t - (30 - 18) \times 5/2 = 300$	M1A1	Subtracts their areas to get 300	
		ii	$t = 11$	A1		
		ii	*OR*			
		ii	Distance while accelerating = $(18 + 30) \times 5/2$	B1	120	
		ii	Distance at constant speed = $30(t - 5)$	B1	May be implied. Tolerate $30t$. Algebraic.	
		ii	Distance at constant speed = $300 - 120 = 30(t - 5)$	M1A1	*OR* $180 = 30t$ M1, $t = 6$ A1	
		ii	$t = 11$	A1		
		ii	Splitting area horizointally			

		ii	Distance = 18*t*	B1	Lower portion of area	
		ii	Distance = (*t* + [*t* − 5]) × (30 − 18)/2	B1	Upper portion of area	
		ii	18*t* + (*t* + [*t* − 5]) × (30 − 18)/2 = 300	M1A1	30*t* − 30 = 300	
		ii	*t* = 11	A1		
		iii	$S = 30^2/(2 \times (\pm 6))$	M1	$0^2 = 30^2 \pm 2 \times 6S$, with candidate's *v*(i)	
		iii	*S* = 75	A1		
		iii	Distance = 375 m	A1ft	300 + cv(75)	
		iii	*OR*	M1	Accept *T* = 5 if no working or from 30/−6, with candidate's *v*(i)	
		iii	*T* = 30/6 and *S* = 30*T*/2			
		iii	*S* = 75	A1		
					300 + cv(75)	
		iii	Distance = 375 m	A1ft	**Examiner's Comments** Many fully correct solutions were seen. The most frequent error was not realising in part (ii) that 300 m was the entire journey distance while both accelerating and moving with constant speed. Thus "300/30 = 10, 10 + 5 = 15 seconds" was the most common mistake seen. Very many candidates expressed their work in a very informal way, their solutions consisting predominantly of numbers (120, 180, 6, 11) without much explanation of what they meant. Candidates could directly find in part (iii) the distance while decelerating (from $0^2 = 30^2 - 2 \times 6s$), and so those who first calculated a time while decelerating needed to use that time to find a distance before becoming eligible for any mark.	
			Total	10		
2		i	5/(*T* − 3) = −4 *OR* 5/(3 − *T*) = 4	M1	Accept verification, 4 × (3 − 1.75) M1	
		i	*T* = 1.75	A1	= 5 A1 *OR* 5/(3 − 1.75) M1 = 4 A1	
		ii	**(a)** -4 ms^{-1}	B1		
		ii	**(b)** 4 ms^{-1}	B1		
		ii	**(c)** 4 ms^{-1}	B1		
		iii	2 × (−)4, 2 × 4, (1 ×)4	M1*	Calculates any one unknown distance	Allow if only one

		iii	$d = (–)5 + (–)8 + 8 + 4$	D*M1	Adds 5 and "3 other" distances or –5 and "3 other" displacements	calc. correct Note t = 5 to t = 9, t = 5 to t = 10 etc, may be one term
		iii	$d = 25$ m	A1	Correctly comes from 4 × (1.25 + 4 + 1) 3/3	
		iv	$v = d(20t - t^2 - 96)/dt$	M1*	Differentiates x, accept $20 - t$ as "differentiation"	
		iv	$v = 20 - 2t$	A1		
		iv	$20 - 2t = -4$	D*M1	$20 - 2t + c = -4$ is DM0	
		iv	$t = 12$ (ignore any solutions less than 10)	A1	Only from $20 - 2t = -4$. This answer can arise fortuitously from solving $20t - t^2 - 96 = 0$. **Examiner's Comments** In recent examinations, a (t, v) graph has been presented to candidates. It was clear that a minority of candidates used methods inappropriate to a (t, x) diagram. Others wrongly used constant acceleration formulae, in a problem where changes of velocity are instantaneous. Only the best candidates were able to solve fully, as only they realised that a speed of 4 m s^{-1} was consistent with $v = -4$.	SC Verifying that t = 12 gives v = –4 can gain final M1A1 (A special case of trial and refinement)
			Total	**12**		
3		i	$v^2 = 3.5^2 + 2g \times 5$	M1	Uses $v^2 = 3.5^2 +/- 2g5$	Accept -3.5^2 for $(-3.5)^2$ etc
		i	$v = 10.5$ ms^{-1}	A1	**Examiner's Comments** Was almost always answered correctly.	
		ii		M1	$+/-5 = 0.87u +/- g\,0.87^2/2$	May come from $s = vt - gt^2/2$
		ii	$5 = 0.87u - g \times 0.87^2 /2$	A1		
		ii	$u = 10.0$ ms^{-1}	A1	**Examiner's Comments** This part was almost always answered correctly, save for a significant minority of candidates who	

					had the wrong sign before the term involving *g*. One unusual feature was the high proportion of candidates who rearranged the standard *suvat* equation into a form which had *u* as its subject.	
		iii	Change = 0.2 × 10.5 + 0.2 × 10	M1	Or +/– 0.2(Ans(i) +/– Ans(ii)) It is OK get –4.1 from correct work	
		iii	Change = 4.1(0) kg ms^{-1}	A1	**Examiner's Comments** Was nearly always answered by subtracting the magnitudes of the momentum on landing and on lift-off. A minority of candidates used the initial speed of 3.5 m s^{-1} in their calculations.	
			Total	7		
4		i	Object fall = $9.8 \times 1.5^2/2$ Ball rise = $18 \times 1.5 - 9.8 \times 1.5^2/2$ Distance = 11.025 + 15.975 Distance = 27 m — AG *OR* Distance fallen = $9.8t^2/2$ Distance risen = $18t - 9.8t^2/2$ $9.8t^2/2 + 18t - 9.8t^2/2 = 27$ $t = 1.5$ — AG	B1 B1 M1 A1 [4] B1 B1 M1 A1	11.025 m 15.975 m Appropriate signs and full accuracy Solves total of distances equation **SC** $18 \times 1.5 = 27$ B1 only but $9.8 \times 1.5^2/2 + 18 \times 1.5 - 9.8 \times 1.5^2/2 = 27$ B1B1M1A1 $9.8t^2/2$ without the context of “distance fallen” is B0. Similarly for $18t - 9.8t^2/2$ **Examiner’s Comments** In part (i), candidates were asked to “verify” t =1.5 which indicated that finding the distances moved by the object and ball should first be calculated. The next stage was to demonstrate that these distances added together equalled the 27 m initial gap. This stage had to be done using exact arithmetic; the use of rounded figures could lead only to the conclusion that the ball and object were very close. Some candidates successfully set	

					up and solved and equation in t containing two squared terms (which subsequently cancelled) and so showed that t =1.5.	
		ii	Object vel (=9.8 x 1.5) = 14.7 m s^{-1} (down) Ball vel =+/−(18 − 9.8 x 1.5) Ball vel = 3.3 (upwards)	B1 M1 A1 [3]	Accept −14.7 m s^{-1} Must be a difference expression 3.3 if v=18 or −3.3 if v = −18 Candidates may find object velocity and ball velocity in (i). **These answers must be quoted here for 3 marks to be given.** Examiner's Comments Part (ii) was done well.	
		iii	$14.7m - 3.3m = 2mu$ $u = 5.7$ $15.975 = 5.7t + 9.8t^2/2$ Solve $4.9t^2 + 5.7t - 15.975 = 0$ $t = 1.32$ s	M1 A1 M1* D*M1 A1 [5]	Momentum conservation; after mass = 2xbefore mass Must use coalesced velocity and s<27 3 term QE and evidence of method of solution if answer incorrect. Disregard signs $v^2 = 5.7^2 + 2 \times 9.8 \times 15.975$ and $v = 5.7 + 9.8t$ Create both M1* Find v (=18.537..), solve for t D*M1 Answer t = 1.32 s Examiner's Comments Part (iii) was often accompanied by diagrams which showed a horizontal collision. The momentum equation proved awkward, with uncertainty about the direction of motion signs, both before and after coalescence, or not having the "after" mass doubled.	

			Total	12	