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MATHEMATICS (9709) P4

TOPIC WISE QUESTIONS + ANSWERS | COMPLETE SYLLABUS

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Appendix A

Answers

1. 9709_s20_MS_41 Q: 1

	Resultant $= 100 - 2 \times 50\cos\alpha$	**M1**
	20 N	**A1**
	Direction is to the left (or equivalent)	**B1**
		3

2. 9709_s20_MS_42 Q: 2

	Resolving forces in either direction	**M1**
	$20\cos\theta = 4P\cos 30$	**A1**
	$4P + 2P\sin 30 = 20\sin\theta$	**A1**
	$\cos\theta = \frac{\sqrt{3}}{10}P$ $\sin\theta = \frac{P}{4}$ $\frac{3}{100}P^2 + \frac{1}{16}P^2 = 1$	**M1**
	$P = 3.29$	**A1**
	$\theta = 55.3$	**A1**
		6

3. 9709_s20_MS_42 Q: 3

	$T\sin 60 + R = 25\cos 20$	B1
	Attempt at resolving in any direction	M1
	$T\cos 60 = F + 25\sin 20$	A1
	$T\cos 60 + F = 25\sin 20$	A1
	Use of $F = \mu R$	M1
	$T\cos 60 = 25\sin 20 \pm 0.3(25\cos 20 - T\sin 60)$ $T = \dfrac{25\sin 20 \pm 0.3\times 25\cos 20}{\cos 60 \pm 0.3\sin 60}$	M1
	$T = 6.26$	A1
	$T = 20.5$	A1
		8

4. 9709_s20_MS_43 Q: 3

	Attempt to resolve, either direction with correct number of terms	M1
	$F\cos\alpha = 40\sin 30 + 20\sin 60 - 50\sin 45\ (= 1.965...)$	A1
	$F\sin\alpha = 50\cos 45 + 20\cos 60 - 40\cos 30\ (= 10.714...)$	A1
	Method for either F or α	M1
	$F = \sqrt{\left((1.965...)^2 + (10.714...)^2\right)} = 10.9(10.893)$	A1
	$\alpha = \tan^{-1}(10.714... / 1.965...) = 79.6\ (79.606...)$	A1
		6

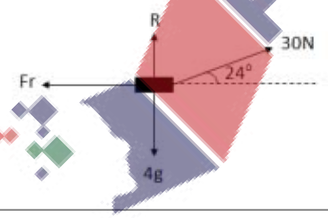
5. 9709_W20_MS_41 Q: 3

	Answer	Mark	Partial Marks
	Resolve forces either horizontally or vertically	M1	Correct number of relevant terms
	$P\cos\theta = 12 + 8\cos 30 - 10\cos 45\ [= 11.857]$	A1	
	$P\sin\theta = 10\sin 45 - 8\sin 30\ [= 3.071]$	A1	
	$P = \sqrt{\left(11.857^2 + 3.071^2\right)}$	M1	OE. Use of correct method for finding P
	$\theta = \tan^{-1}\left(\dfrac{3.071}{11.857}\right)$	M1	OE. Use of correct method for finding θ
	$P = 12.2$ and $\theta = 14.5$	A1	Both correct
		6	

6. 9709_W20_MS_42 Q: 3

	Answer	Mark	Partial Marks
	$20\cos 60 = T\cos 45$	M1	Resolve forces horizontally, 2 terms
	$T = 10\sqrt{2}$ or $T = 14.1$	A1	
	$20\sin 60 + T\sin 45 = mg$ or W	M1	Resolve forces vertically, 3 terms
	$20\sin 60 + T\sin 45 = mg$	A1	
	$m = 2.73$ [$= \sqrt{3} + 1$]	A1	
	Alternative method for question 3		
	$\left[\frac{T}{\sin 150} = \frac{mg \text{ or } W}{\sin 75} = \frac{20}{\sin 135}\right]$	M1	Attempt at one pair of terms using Lami's Method
	$\frac{T}{\sin 150} = \frac{mg}{\sin 75} = \frac{20}{\sin 135}$	A1	All terms correct in Lami's Method
	Attempt to solve for either T or m or W	M1	
	$T = 10\sqrt{2}$ or $T = 14.1$	A1	
	$m = 2.73$ [$= \sqrt{3} + 1$]	A1	
		5	
	Alternative method for question 3		
	$\left[\frac{T}{\sin 30} = \frac{mg \text{ or } W}{\sin 105} = \frac{20}{\sin 45}\right]$	M1	Attempt the triangle of forces method and state one equation which involves any two of the forces T, m and 20.
	$\frac{T}{\sin 30} = \frac{mg}{\sin 105} = \frac{20}{\sin 45}$	A1	All correct
	Attempt to solve for either T or m or W	M1	
	$T = 10\sqrt{2}$ or $T = 14.1$	A1	
	$m = 2.73$ [$= \sqrt{3} + 1$]	A1	
		5	

7. 9709_W20_MS_43 Q: 3

	Answer	Mark	Partial Marks
(a)		B1	4 forces, labelled
		1	
(b)	For resolving horizontally or vertically	M1	
	$30\cos 24 = F$ $(F = 27.406\ldots)$	A1	
	$R + 30\cos 24 = 40$ $(R = 27.797\ldots)$	A1	
	$\mu = \frac{30\cos 24}{40 - 30\sin 24}$	M1	Using $\mu = F/R$
	$\mu = 0.986$ $(0.9859\ldots)$	A1	
		5	

8. 9709_m19_MS_42 Q: 1

	Answer	Mark	Partial Marks
	$R = 2.5 \cos 15$	**B1**	
	$[F = \mu \times 2.5 \cos 15]$	**M1**	Using $F = \mu R$
	$[2.5 \sin 15 = 0.03g + F]$	**M1**	Resolve forces along the rod
	$\mu = 0.144$	**A1**	
		4	

9. 9709_m19_MS_42 Q: 3

	Answer	Mark	Partial Marks
		M1	Attempt to resolve forces horizontally or vertically
	$F \cos \alpha = 15 \cos 20 - 5$ $(= 9.095...)$	**A1**	
	$F \sin \alpha = 15 \sin 20 + 25$ $(= 30.13....)$	**A1**	
	$F = \sqrt{(15\cos 20 - 5)^2 + (15\sin 20 + 25)^2}$	**M1**	Use Pythagoras or trigonometry to find F
	$\alpha = \tan^{-1}\left[(15\sin 20 + 25)/(15\cos 20 - 5)\right]$	**M1**	Use trigonometry to find α
	$\alpha = 73.2$ **and** $F = 31.5$	**A1**	
		6	

10. 9709_s19_MS_41 Q: 1

	Answer	Mark	Partial Marks
	$(X =)$ 78 □ 5/13 – 50 × 3/5 = 78 cos 67.4 – 50 cos 53.1 $(Y =)$ 78 □ 12/13 □ 50 × 4/5 – 112 = 78 sin 67.4 □ 50 sin 53.1 – 112	**M1**	Attempt to resolve forces either horizontally (2 terms) or vertically (3 terms)
	$[X = 30 - 30 = 0$ $Y = 72 + 40 - 112 = 0]$	**A1**	Correct expressions horizontally and vertically
	$X = 0$ and $Y = 0$	**A1**	From convincing exact calculations
	Alternative method for question 1		
	$\frac{112}{\sin 59.5}$ □ $\frac{50}{\sin 157.4}$ □ $\frac{78}{\sin 143.1}$	**M1**	Attempt to use Lami, one pair of terms
		A1	All terms correct
	$\frac{112}{56/65}$ □ $\frac{50}{5/13}$ □ $\frac{78}{3/5}$ □130	**A1**	Exact values seen and used and shown to be = 130 cos [180 – (θ + α)] = 33/65 and sin [180 – (θ + α)] = 56/65
		3	

11. 9709_s19_MS_42 Q: 1

	Answer	Mark	Partial Marks
	[$P\cos\theta = 32\cos 20 - 17\sin 55$] [$P\sin\theta = 40 + 17\cos 55 - 32\sin 20$]	M1	Resolve forces horizontally or vertically 3 terms horizontally, 4 terms vertically
		A1	One correct
		A1	Both correct [$P\sin\theta = 38.8062$ $P\cos\theta = 16.1446$]
	$P = \sqrt{(17\cos 55 - 32\sin 20 + 40)^2 + (32\cos 20 - 17\cos 35)^2}$	M1	Either use Pythagoras to find P or use their value of θ to find P
	$\theta = \tan^{-1}\left[\frac{(17\cos 55 - 32\sin 20 + 40)}{(32\cos 20 - 17\cos 35)}\right]$	M1	Either use trigonometry to find θ or use their value of P to find θ [$\tan\theta = 2.4037$]
	$P = 42(.0)$ **and** $\theta = 67.4$	A1	
		6	

12. 9709_s19_MS_43 Q: 2

	Answer	Mark	Partial Marks
(i)	[24cos25° – 12cos65°]	M1	Resolving in x-direction
	16.7 N	A1	(16.679...)
	[30 – 24sin25° – 12sin65°]	M1	Resolving in y-direction
	8.98 N	A1	(8.981...)
		4	
(ii)	[$\tan^{-1}\frac{8.98\ldots}{16.67\ldots}$]	M1	Uses trigonometry to find the angle
	28.3° (anticlockwise) from x-direction	A1	(28.300...) or equivalent
		6	

13. 9709_w19_MS_42 Q: 3

	Answer	Mark	Partial Marks
	$T_A \times \frac{4}{5} + T_B \times \frac{3}{5} + 0.3g = 5$	M1	Resolving vertically
	$T_A \times \frac{3}{5} = T_B \times \frac{4}{5}$	M1	Resolving horizontally
		A1	Both correct
		M1	Solve for T_A or T_B
	$T_A = 1.6$ N and $T_B = 1.2$ N	A1	
	Alternative method for question 3		
	$\left[\frac{5-3}{\sin 90} = \frac{T_A}{\sin 126.9} = \frac{T_B}{\sin 143.1}\right]$	M1	Attempt one pair of Lami's equations
		M1	Attempt a second pair of Lami equations
		A1	Equations all correct
		M1	Evaluate T_A or T_B
	$T_A = 1.6$ N and $T_B = 1.2$ N	A1	
	Alternative method for question 3		
	$T_A = 5\cos 36.9 - 3\cos 36.9 = 5 \times \frac{4}{5} - 3 \times \frac{4}{5}$	M1	Resolve along *PA*
	$TB = 5\cos 53.1 - 3\cos 53.1 = 5 \times \frac{3}{5} - 3 \times \frac{3}{5}$	M1	Resolve along *PB*
		A1	Both correct
		M1	Evaluate T_A or T_B
	$T_A = 1.6$ N and $T_B = 1.2$ N	A1	
	Alternative method for question 3		
	Forces 2N, T_A and T_B with angles 36.9 and 53.1	M1	Attempt to illustrate a triangle of forces
	[$T_A = 2\cos 36.9$, $T_B = 2\cos 53.1$]	M1	Use trigonometry in the triangle to find T_A and T_B
		A1	Both correct
		M1	Solve for T_A or T_B
	$T_A = 1.6$ N and $T_B = 1.2$ N	A1	
		5	

14. 9709_w19_MS_43 Q: 1

	Answer	Mark	Partial Marks
	$F=\mu\times 500g$	B1	Use of $F=\mu R$
	[$2500=\mu\times 500g$]	M1	Resolving horizontally
	$\mu=0.5$	A1	
		3	

15. 9709_w19_MS_43 Q: 3

	Answer	Mark	Partial Marks
	Resolving horizontally or vertically	M1	
	50cos20 + 60 – 100sin30 (=56.984…)	A1	
	100cos30 – 50sin20 (= 69.501…)	A1	
	$R = \sqrt{(56.984...^2 + 69.501...^2)}$ or $\alpha = \tan^{-1}\left(\frac{56.984...}{69.501...}\right)$	M1	Method to find either R or α
	R=89.9 (89.876…)	A1	
	α=39.3 (39.348…)	A1	
		6	

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16. 9709_m18_MS_42 Q: 2

	Answer	Mark	Partial Marks
	EITHER: $2P \sin\theta = P \sin 60$	(M1	Resolve vertically (2 terms)
	$\theta = 25.7$	A1	
	$2P\cos\theta + P\cos 60 = 10$	M1	Resolve horizontally (3 terms)
	$P = 4.34$	A1)	
	OR1: $\left[\frac{2P}{\sin 120} = \frac{P}{\sin(180-\theta)} = \frac{10}{\sin(60+\theta)}\right]$	(M1	Attempt Lami's theorem using one pair of terms
	$\theta = 25.7$	A1	Solve for θ
	Use a second Lami equation	M1	
	$P = 4.34$	A1)	
	OR2: Use sine or cosine rule with triangle of forces using forces P, $2P$ and 10 and with angles 60, θ and $120 - \theta$ between	(M1	
	$\theta = 25.7$	A1	
	Use a second relationship from the triangle of forces	M1	
	$P = 4.34$	A1)	
		4	

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17. 9709_s18_MS_41 Q: 2

	Answer	Mark	Partial Marks
	[10 cos α = 8 or 10 cos β = 6]	M1	Introduce α or β, an angle between the 10N force and the vertical or horizontal and attempt to resolve forces
	α = 36.9 or β = 53.1	A1	
	Angle between 6N and 10N is 126.9	B1	
	Angle between 8N and 10N is 143.1	B1	
		4	
	Alternative scheme for Question 2		
	$\frac{10}{\sin 90}=\frac{6}{\sin\gamma}=\frac{8}{\sin\delta}$	M1	Attempt to use Lami's theorem γ (8 and 10), δ (6 and 10)
	All correct	A1	
	Angle between 8N and 10N is γ =143.1	B1	
	Angle between 6N and 10N is δ =126.9	B1	

18. 9709_s18_MS_42 Q: 3

	Answer	Mark	Partial Marks
	[3 cos 60 = 2 cos θ]	M1	Attempt to resolve forces horizontally (2 terms)
	θ = 41.4	A1	
	[P = 3 sin 60 + 2 sin θ]	M1	Attempt to resolve forces vertically (3 terms)
	P = 3.92	A1	
		4	
	First alternative method for Q3		
	$\frac{P}{\sin(120-\theta)}=\frac{2}{\sin 150}=\frac{3}{\sin(90+\theta)}$	M1	Attempt two terms of Lami's equation which can be used to find θ
	θ = 41.4	A1	
		M1	Attempt an equation which can be used to find P
	P = 3.92	A1	
	Second alternative method for Q3		
	[Triangle with sides 2, 3, P and angles opposite of 30, 90 – θ, 60 + θ] $\frac{P}{\sin(60+\theta)}=\frac{2}{\sin 30}=\frac{3}{\sin(90-\theta)}$	M1	Attempt two terms from the triangle of forces which can be used to find θ
	θ = 41.4	A1	
		M1	Attempt an equation which can be used to find P
	P = 3.92	A1	

19. 9709_s18_MS_42 Q: 5

	Answer	Mark	Partial Marks
	$R = 20g \cos 60$ [= 100]	B1	
	$F = \mu \times 20g \cos 60$ [= 100μ]	M1	Use $F = \mu R$
		M1	Resolve along plane in either case
	$(P_{max} =)$ $20g \sin 60 + F$	A1	One correct equation
	$(P_{min} =)$ $20g \sin 60 - F$	A1	Second correct equation
	$20g \sin 60 + F = 2(20g \sin 60 - F)$	M1	Use of $P_{max} = 2P_{min}$ to give four term equation in F or μ or P
	$\mu = \frac{\sqrt{3}}{3} = 0.577$	A1	
		7	
	lternative solution for final 3 marks if P_{min} is taken as acting down the plane		
	$P_{min} = F - 20g \sin 60$	A1	
	$20g \sin 60 + F = 2(F - 20g \sin 60)$	M1	
	$\mu = 3\sqrt{3} = 5.196$	A1	

20. 9709_s18_MS_43 Q: 3

	Answer	Mark	Partial Marks
		M1	For resolving forces in any one direction
	E.g. $X = 18 + 12\sin 60° - 8\sin 30°$ $14 + 6\sqrt{3}$	A1	One correct equation or expression
	E.g. $Y = 8\cos 30° + 12\cos 60°$ $6 + 4\sqrt{3}$	A1	Second correct equation or expression (X and Y may denote components of resultant of given 3 forces or may be components of the fourth force that would produce equilibrium)
	$[(14 + 6\sqrt{3})^2 + (6 + 4\sqrt{3})^2]$ or $[\tan^{-1} (6 + 4\sqrt{3})/(14 + 6\sqrt{3})]$	M1	Use of Pythagoras or appropriate trig to find magnitude or angle
	Magnitude is 27.6 (N)	A1	Not for resultant
	Direction is 27.9° below 'negative x-axis'	A1	Not for 27.9° only; direction must be clearly specified
	Total:	6	

21. 9709_s18_MS_43 Q: 5

	Answer	Mark	Partial Marks
	$R = 3g \cos 20°$	B1	Correct normal reaction stated or used
	$[F = 0.35 \times 3g \cos 20°]$	M1	For use of $F = \mu R$
	$[P_1 + F = 3g \sin 20°]$	M1	Attempted resolving equation for minimum case
	$P_1 = 0.394$ **(AG)**	A1	Correct given answer from correct work
	$[P_2 = F + 3g \sin 20°]$	M1	Attempted resolving equation for maximum case
	$P_2 = 20.1$ (N)	A1	
	Total:	6	

22. 9709_w18_MS_41 Q: 5

	Answer	Mark	Partial Marks
(i)		M1	For resolving forces horizontally or vertically o.e.
	25 cos 30 – 15 cos 40 (= 10.1599…)	A1	
	25 sin 30 + 15 sin 40 – 30 (= –7.8581…)	A1	
		M1	For using a method for either magnitude or direction
	Magnitude = $\sqrt{(10.15...^2 + 7.858...^2)}$ = 12.8 N	A1	Magnitude = 12.844…
	Angle 37.7° below the horizontal in the direction *BA*	A1	
		6	
(ii)	*F* cos 40 = 25 cos 30	M1	For equating forces in the direction *BC* to zero
	F = 28.3	A1	*F* = 28.2628…
	New resultant force = 28.26…sin 40 + 25 sin 30 – 30 = 0.667 N upwards	B1	
		3	

23. 9709_w18_MS_42 Q: 1

	Answer	Mark	Partial Marks
	[*T* cos 45 + *T* cos 45 = 2.5 cos 45]	M1	For resolving horizontally
	T = 1.25 N	A1	
	[2.5 sin 45 = *mg*]	M1	For resolving vertically
	Mass of ring = 0.177 kg	A1	Allow *m* = √2/8
	First alternative method for Q1		
	[2.5 = *T* + *mg* cos 45]	M1	Resolve forces along BR
	[*T* = *mg* cos 45]	M1	Resolve forces perpendicular to BR and eliminate *T* or *m*
	T = 1.25 N	A1	
	Mass of ring = 0.177 kg	A1	Allow *m* = √2/8
	Second alternative method for Q1		
	$\frac{2T\cos 45}{\sin 135} = \frac{2.5}{\sin 90} = \frac{mg}{\sin 135}$ or $\frac{2.5-T}{\sin 135} = \frac{T}{\sin 135} = \frac{mg}{\sin 90}$	M1	Attempt to apply Lami's theorem,
		M1	All three terms of Lami attempted
	T = 1.25 N	A1	
	Mass of ring = 0.177 kg	A1	Allow *m* = √2/8
		4	

24. 9709_w18_MS_42 Q: 2

	Answer	Mark	Partial Marks
	$R = 5g\cos 6$	B1	
	$[F = 0.3 \times 5g\cos 6]$	M1	Use of $F = \mu R$
	$[T = 5g\sin 6 + F]$	M1	For resolving along the plane
	$T = 20.1$ N (20.14425...)	A1	
		4	

25. 9709_w18_MS_43 Q: 1

	Answer	Mark	Partial Marks
	$[T\sin 70 + T\sin 45 = 0.2\,g]$	M1	Resolving vertically
	$T = 1.21$ N (1.21447…)	A1	
	$[P + T\cos 70 = T\cos 45]$	M1	Resolving horizontally
	$P = 0.443$ (0.443389…)	A1	
		4	

26. 9709_w18_MS_43 Q: 2

	Answer	Mark	Partial Marks
	$R = mg + 50\sin 20$	B1	
	$[F = 0.3(mg + 50\sin 20)]$	M1	Use of $F = \mu R$
		M1	Resolving horizontally
	$50\cos 20 - 0.3(mg + 50\sin 20) = 0$	A1ft	ft R (R containing term in m)
	$m = 14.0$kg (13.9514…)	A1	
		5	

27. 9709_m17_MS_42 Q: 2

	Answer	Mark	Partial Marks
		M1	Resolve forces horizontally and/or vertically
	$T_A \sin 20 + T_B \sin 40 = 16$	A1	Correct vertical equation
	$T_A \cos 20 = T_B \cos 40$	A1	Correct horizontal equation
		M1	Attempt to solve for T_A and/or T_B
	$T_A = 14.2\,\text{N}$	A1	$T_A = 14.1528...$
	$T_B = 17.4\,\text{N}$	A1	$T_B = 17.3610...$
	Total:	**6**	
	Alternative method for Question 2		
		M1	Attempt to use Lami's Theorem
	$\dfrac{16}{\sin 120} = \dfrac{T_A}{\sin 130}$	A1	
	$\dfrac{16}{\sin 120} = \dfrac{T_B}{\sin 110}$	A1	
		M1	Attempt to solve for T_A and/or T_B
	$T_A = 14.2\,\text{N}$	A1	
	$T_B = 17.4\,\text{N}$	A1	
	Total:	**6**	

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28. 9709_m17_MS_42 Q: 3

	Answer	Mark	Partial Marks
	$R = 0.6g \cos 21$ [= 5.60]	B1	
	$F = 0.3R = 1.8 \cos 21$ [= 1.68]	M1	Using $F = \mu R$
	$P + F = 6 \sin 21$[= 2.15]	M1	Slipping down
	$P = 2.15 - 1.68 = 0.470$ **AG**	A1	Least possible value
	$P - F = 6 \sin 21$	M1	Slipping up
	$P = 2.15 + 1.68 = 3.83$	A1	Greatest possible value
	Total:	**6**	

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29. 9709_s17_MS_41 Q: 3

	Answer	Mark	Partial Marks
	EITHER:	(M1	Resolve horizontally and/or vertically at the 25 N weight
	$A\cos 30 + B\cos 40 = 25$	A1	
	$A\sin 30 = B\sin 40$	A1	
		M1	Solve for A and/or B
	$A = 17.1$	A1	
	$B = 13.3$	A1)	
	OR:	(M1	Attempt Lami's theorem
	$\frac{25}{\sin 70} = \frac{A}{\sin 140} = \frac{B}{\sin 150}$	A1	One correct equation
		A1	A second correct equation
		M1	Solve for A and/or B
	$A = 17.1$	A1	
	$B = 13.3$	A1)	
	Total:	**6**	

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30. 9709_s17_MS_42 Q: 5

	Answer	Mark	Partial Marks
		M1	Resolve perpendicular to the plane, three terms
	$R + P\sin 30 = 0.12g\cos 40$	A1	R does not need to be the subject
	$F = 0.32R$	M1	Use $F = \mu R$
	$[P_{min}\cos 30 + F = 0.12g\sin 40]$	M1	About to slip down, 3 terms
	$[P_{max}\cos 30 - F = 0.12g\sin 40]$	M1	About to slip up, 3 terms
	$[P\cos 30 = 0.12g\sin 40$ $\pm 0.32(0.12g\cos 40 - P\sin 30)]$ OR $[P\cos 30 \pm 0.32R = 0.12g\sin 40$ $R + P\sin 30 = 0.12g\cos 40]$ Must reach $P = \ldots$ in either method	M1	Substitute for F and solve for P in either case, 4 terms OR solve a pair of simultaneous equations (each with 3 terms) in R and P for P in one of the cases
	$P_{max} = 1.04$ $P_{min} = 0.676$	A1	For either correct
	$0.676 \leqslant P \leqslant 1.04$	A1	
	Total:	**8**	

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31. 9709_s17_MS_43 Q: 2

	Answer	Mark	Partial Marks
	EITHER: $3P\sin 55 + P\sin\theta = 20 + P\sin\theta$ or $3P\sin 55 = 20$	(M1	Resolves forces vertically
	$P = 8.14$	A1	
	$3P\cos 55 = 2P\cos\theta$	M1	Resolves forces horizontally
	$\cos\theta = 1.5\cos 55 \rightarrow \theta = \ldots$	M1	Attempt to solve for θ
	$\theta = 30.6$	A1)	
	OR: $\frac{3P}{\sin 90} = \frac{20}{\sin 125}$	(M1	Uses Lami's Theorem (forces $3P$ and 20)
	$P = 8.14$	A1	
	$\frac{3P}{\sin 90} = \frac{2P\cos\theta}{\sin 145}$	M1	Uses Lami's Theorem (forces $3P$ and $2P\cos\theta$)
	$\cos\theta = 1.5\sin 145 \rightarrow \theta = \ldots$	M1	Attempt to solve for θ
	$\theta = 30.6$	A1)	
	Total:	5	

32. 9709_w17_MS_41 Q: 6

	Answer	Mark	Partial Marks
(i)		M1	For resolving forces (either direction)
	$X = 75 + 50\cos 60\ (= 100)$ $Y = 50\sin 60\ (= 43.3)$	A1	For both equations, unevaluated
	Resultant $= \sqrt{(100^2 + 43.3^2)} = 109$ N	B1	
	Angle $= \arctan\left(\frac{43.3}{100}\right) = 23.4°$	B1	Must state anticlockwise from the positive x-axis or show in a diagram
		4	
(ii)	$50\cos\alpha - F\cos 50 = 0$	B1	Resolving forces horizontally
	$50\sin\alpha - 3F - F\sin 50 = 0$	B1	Resolving forces vertically
	$\tan\alpha = \frac{(3F + F\sin 50)}{(F\cos 50)}$	M1	For division to find θ or for using Pythagoras to find F
	$\alpha = 80.3$	A1	
	$F = 13.1$	A1	
		5	

33. 9709_w17_MS_42 Q: 2

	Answer	Mark	Partial Marks
	EITHER:	(M1	Attempt to resolve (either direction with correct number of terms and dimensionally correct)
	$T\sin\theta + 120\sin 45 = 15g$	A1	Resolving vertically
	$T\cos\theta = 120\cos 45$	A1	Resolving horizontally
	$[\tan\theta = \frac{(15g - 120\sin 45)}{(120\cos 45)}$ or $T = \sqrt{65.15^2 + 84.85^2}$]	M1	For using division to find θ or for using Pythagoras to find T
	$\theta = 37.5$	A1	
	$T = 107$	A1)	
	OR1: $\frac{120}{\sin(90+\theta)} = \frac{T}{\sin 135} = \frac{15g}{\sin(135-\theta)}$	(A1	One correct equation
		A1	A second correct equation
		M1	Attempt to solve for θ or T
	$\theta = 37.5$	A1	
	$T = 107$	A1	
		M1)	Attempt to use triangle of forces
	OR2: $\frac{T}{\sin 45} = \frac{15g}{\sin(45+\theta)} = \frac{120}{\sin(90-\theta)}$	(A1	One correct equation
		A1	A second correct equation
		M1	Attempt to solve for θ or T
	$\theta = 37.5$	A1	
	$T = 107$	A1)	
	OR3: $[T^2 = 150^2 + 120^2 - 2(150)(120)\cos 45]$	(M1	Use cosine rule in a triangle with sides 120, 150 and T and with corresponding angles $90 - \theta$, $45 + \theta$, 45
		A1	Correct equation
	$T = 107$	A1	
		M1	Use sin rule or cosine rule in an attempt to find θ
	$120/\sin(90 - \theta) = 106.97/\sin 45$	A1	A correct equation in θ such as this
	$\theta = 37.5$	A1)	
		6	

34. 9709_w17_MS_43 Q: 1

	Answer	Mark	Partial Marks
	(X=) 20 cos 60 + 30 cos 60 – F	**B1**	
	[F = 20 cos 60 + 30 cos 60]	**M1**	Use of horizontal component of resultant = 0
	F = 25	**A1**	
		3	

35. 9709_m16_MS_42 Q: 3

	Answer	Mark		Partial Marks
(i)		**M1**		For resolving forces horizontally
	R_x = 40 × (24/25) – 30 × (7/25) [= 30]	**A1**		Allow R_x = 40 cos 16.3 – 30 sin 16.3
		M1		For resolving forces vertically
	R_y = 50 – 40 × (7/25) – 30 × (24/25) [= 10]	**A1**		Allow R_y = 50 – 40 sin16.3 – 30 cos16.3
	$R = \sqrt{R_x^2 + R_y^2}$ **and** $\theta = \tan^{-1}\left(R_y / R_x\right)$	**M1**		For using Pythagoras to find the resultant force R **and** trigonometry to find the angle θ made by the resultant with the x-axis
	R = 31.6 N **and** θ = 18.4° with the positive x-axis	**A1**	6	
	Alternative method for 3(i)			
(i)		**M1**		Resolve forces along 40 N direction
	R_1 = 40 – 50 × (7/25) [= 26]	**A1**		Allow R_1 = 40 – 50 sin 16.3
		M1		Resolve forces along 30 N direction
	R_2 = 30 – 50 × (24/25) [= –18]	**A1**		Allow R_2 = 30 – 50 cos 16.3
	$R^2 = {R_1}^2 + {R_2}^2$ **and** arctan($-R_2/R_1$)	**M1**		Use Pythagoras **and** trigonometry
	R = 31.6 N **and** direction is 34.7 – α = 18.4° with positive x–axis	**A1**	6	Using arctan(18/26) = 34.7° is the angle between R and the 40 N force
(ii)	P = 40	**B1**	1	

36. 9709_s16_MS_41 Q: 4

	Answer	Mark		Partial Marks
	$P\cos\theta = 48\cos\alpha - 14\sin\alpha$ and/or $P\sin\theta = 50 - 48\sin\alpha - 14\cos\alpha$	M1		For resolving forces horizontally and/or vertically
	$P\cos\theta = 48(24/25) - 14(7/25)$ $= 42.16$	A1		Allow α = 16.3 used throughout
	$P\sin\theta = 50 - 48(7/25) - 14(24/25)$ $= 23.12$	A1		
		M1		For attempting to find P or θ
	$P = \sqrt{42.16^2 + 23.12^2} = 48.1$	A1		Allow $P = 34\sqrt{2}$
	$\tan\theta = \dfrac{23.12}{42.16}$ $\theta = 28.7$	B1	[6]	

37. 9709_s16_MS_42 Q: 1

	Answer	Mark		Partial Marks
	[$X = 7 - 8\cos\alpha - 6\sin\alpha = -3$]	M1		For resolving forces horizontally
	$X = 7 - 8 \times (4/5) - 6 \times (3/5) = -3$	A1		Allow α = 36.9 used
	[$Y = 8\sin\alpha - 6\cos\alpha = 0$]	M1		For resolving forces vertically
	$Y = 8 \times (3/5) - 6 \times (4/5) = 0$	A1		Allow α = 36.9 used
	Resultant force is 3N to the left	B1	5	

38. 9709_s16_MS_42 Q: 5

	Answer	Mark		Partial Marks
		M1		For resolving forces perpendicular to the plane (3 term equation)
	$R + T\sin 20 = 2.5g\cos 30$	**A1**		
	$F = 0.25 \times R$	**B1**		May be implied
		M1		For resolving forces parallel to the plane (3 term equation)
	$T\cos 20 = F + 2.5g\sin 30$	**A1**		
		M1		For solving and obtaining T
	$T = 17.5$	**A1**	7	
	Alternative scheme			
	$F = 0.25 \times R$	**B1**		May be implied
		M1		For resolving forces horizontally (3 term equation)
	$T\cos 50 = F\cos 30 + R\sin 30$	**A1**		
		M1		For resolving forces vertically (4 term equation)
	$R\cos 30 + T\sin 50 = F\sin 30 + 2.5g$	**A1**		
		M1		For solving and obtaining T
	$T = 17.5$	**A1**	7	

39. 9709_s16_MS_43 Q: 3

	Answer	Mark		Partial Marks
		M1		For resolving forces horizontally and/or vertically
	$12\cos 75^\circ + P\cos\theta^\circ = 18\cos 65^\circ$	**A1**		
	$18\sin 65^\circ + 12\sin 75^\circ = 15 + P\sin\theta^\circ$	**A1**		
	$[P^2 = (18\sin 65^\circ + 12\sin 75^\circ - 15)^2 + (18\cos 65^\circ - 12\cos 75^\circ)^2]$ or $[\theta = \tan^{-1}(18\sin 65^\circ + 12\sin 75^\circ - 15)/(18\cos 65^\circ - 12\cos 75^\circ)]$	**M1**		For eliminating either θ or P from the simultaneous equations
	$P = 13.7$ or $\theta = 70.8$	**A1**		
	$\theta = 70.8$ or $P = 13.7$	**B1**	6	

40. 9709_s16_MS_43 Q: 4

	Answer	Mark		Partial Marks
	$R = 15g\cos 20^\circ$	**B1**		140.95
	$F = \mu R = 0.2 \times 15g\cos 20^\circ$	**B1**		28.19
		M1		For resolving parallel to the plane (F acting up plane)
	$X + 0.2 \times 15g\cos 20^\circ = 15g\sin 20^\circ$	**A1**		
	Least value of X is 23.1	**A1**		AG
	$[X = 15g\sin 20^\circ + 0.2 \times 15g\cos 20^\circ]$	**M1**		For resolving parallel to the plane (F acting down plane)
	Greatest value of X is 79.5	**A1**	7	

41. 9709_w16_MS_41 Q: 4

	Answer	Mark		Partial Marks
		M1		For resolving forces horizontally
	$2F + F\cos60 = 15\cos\alpha$	A1		
		M1		For resolving forces vertically
	$F\sin60 = 15\sin\alpha$	A1		
		M1		For using Pythagoras or for using tan α to find F **and** α
	$F = 5.67$ and $\alpha = 19.1$	A1	[6]	Allow $F = 15\sqrt{7}/7$

42. 9709_w16_MS_42 Q: 3

	Answer	Mark		Partial Marks
(i)	$[X = 60\cos25 + 50\cos15]$	M1		For resolving both forces in the direction of river
	$= 103$ N	A1	[2]	Value of X is 102.7 N
(ii)	$Y = 60\sin25 - 50\sin15$ [= 12.4]	B1		Component perpendicular to the direction of the river
	$[R^2 = X^2 + Y^2]$ or $[\alpha = \arctan(Y/X)]$	M1		For using Pythagoras or for using arctan to find the resultant force or its direction
	Magnitude is 103 N (or α = 6.9° with direction specified unambiguously)	A1		Magnitude is 103.4 N
	α = 6.9° with direction specified unambiguously (or Magnitude = 103 N)	B1	[4]	

43. 9709_w16_MS_42 Q: 5

	Answer	Mark		Partial Marks
	$F = \mu mg\cos 30$	B1		
	$[10 + F - mg\sin 30 = 0]$	M1		Resolving up, first case
	$[75 - F - mg\sin 30 = 0]$	M1		Resolving up, second case
	$[85 = 2mg\sin 30]$ or $[10 + \mu mg\cos 30 - mg\sin 30 = 0$ $75 - \mu mg\cos 30 - mg\sin 30 = 0]$	M1		Either attempt to solve for m or Solve a pair of two 3 term simultaneous equations for either m or μ
	$m = 8.5$ kg or $\mu = 0.442$	A1		
	$\mu = 0.442$ or $m = 8.5$ kg	B1	[6]	

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44. 9709_w16_MS_43 Q: 2

	Answer	Mark		Partial Marks
		M1		For resolving horizontally
		M1		For resolving vertically
	$T_A\cos 50° - T_B\cos 10° = 0$ **and** $T_A\sin 50° - T_B\sin 10° - 20g = 0$	A1		
		M1		For solving equations to find T_A and T_B
	Tension in PA is 306 N Tension in PB is 200 N	A1	[5]	
	Alternative (Lami's Theorem)			
	$[T_A/\sin 80° = T_B/\sin 140° = 20g/\sin 140°]$	M1		For applying Lami's Theorem
	$[T_A=20g\sin 80°/\sin 140°]$	M1		For solving for T_A
	Tension in PA is 306 N	A1		
	$[T_B=20g\sin 140°/\sin 140°]$	M1		For solving for T_B
	Tension in PB is 200 N	A1	[5]	

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45. 9709_s15_MS_41 Q: 2

	Answer	Mark		Partial Marks
		M1		For resolving components of F in x and y directions
	$F_x = F\cos\theta = 25 \times 0.8 = 20$, $F_y = F\sin\theta = 63 - 25 \times 0.6 = 48$	A1		
		M1		For using $F = \sqrt{(F_x^2 + F_y^2)}$ <u>or</u> for using $\tan\theta = F_y \div F_x$
	$F = 52$ N <u>or</u> $\tan\theta = 2.4$	A1		
	$\tan\theta = 2.4$ <u>or</u> $F = 52$ N	B1	5	

46. 9709_s15_MS_42 Q: 7

	Answer	Mark		Partial Marks
(i)		M1		For resolving forces at J horizontally **or** vertically
	$0.8T_A + 0.6T_R = 5.6$	A1		Allow $T_A \cos 36.9 + T_R \cos 53.1 = 5.6$ oe
	$0.6T_A = 0.8T_R$	A1		Allow $T_A \sin 36.9 = T_R \sin 53.1$ oe
		M1		For solving the simultaneous equations for T_A and T_R
	Tension in AJ is 4.48 N **and** tension in RJ is 3.36 N	A1	5	
	First Alternative Method for (i)			
(i)	$\dfrac{5.6}{\sin 90} = \dfrac{T_A}{\sin\alpha} = \dfrac{T_R}{\sin(270-\alpha)}$ m	M1		For applying Lami's theorem to two of the three forces T_A, T_R, and 5.6 where α is an obtuse angle
	$\dfrac{5.6}{\sin 90} = \dfrac{T_A}{0.8} = \dfrac{T_R}{0.6}$ m	A1 A1		Allow sin126.9 for 0.8 and sin143.1 for 0.6 here
		M1		Solve for T_A **and** T_R
	$T_A = 4.48$ **and** $T_R = 3.36$	A1	5	
	Second Alternative Method for (i)			
(i)	$\dfrac{5.6}{\sin 90} = \dfrac{T_A}{\sin\alpha} = \dfrac{T_R}{\sin(90-\alpha)}$ m	M1		For applying triangle of forces to two of the three forces T_A, T_R, and 5.6
	$\dfrac{5.6}{\sin 90} = \dfrac{T_A}{0.8} = \dfrac{T_R}{0.6}$ m	A1 A1		Allow sin 53.1 for 0.8 and sin 36.9 for 0.6 here
		M1		Solve for T_A **and** T_R
	$T_A = 4.48$ **and** $T_R = 3.36$	A1	5	
(ii)	$0.2g + F = T_R \times \cos 36.9$	B1√		ft on T_R and 36.9
	$N = T_R \times \sin 36.9$	B1√		ft on T_R and 36.9
	$[0.2g + \mu \times T_R \times 0.6 = T_R \times 0.8]$	M1		For using $\mu = F \div N$ and obtaining an equation in μ
	$\mu = 0.688 \div 2.016 = 0.341$	A1	4	AG
(iii)	$[0.2g + mg = \mu N + 0.8T_R]$	M1		For a four term equation from resolving forces acting on R vertically.
	$0.2g + mg = 0.341 \times 2.016 + 3.36 \times 0.8$	A1		
	$m = 0.137$ or 0.138	A1	3	

47. 9709_s15_MS_43 Q: 5

	Answer	Mark		Partial Marks
(i)	x-component = 4+8cos30°+12cos60° [= 10 + 4√3]	B1		16.928
	y-component = 8sin30°+12sin60°+16 [= 20 + 6√3]	B1		30.392
		M1		For using $R^2 = X^2 + Y^2$ or tan $\theta = Y \div X$
	R = 34.8 or θ = 60.9° with the 4N force	A1		
	θ = 60.9° with the 4N force or R = 34.8	B1	5	
(ii)	R = 34.8	B1√		ft R from **(i)**
	θ = 29.1° with the 16N force	B1√	2	ft 90 – θ from **(i)**

48. 9709_w15_MS_41 Q: 4

	Answer	Mark		Partial Marks
	$F = 0.2 \times mg \cos 35$	**B1**		Maximum value of F
		M1		For resolving forces along the plane in either case
	$5g - mg \sin 35 - 0.2\, mg \cos 35 = 0$	**A1**		Equilibrium, on the point of moving up the plane
	$5g - Mg \sin 35 + 0.2\, Mg \cos 35 = 0$	**A1**		Equilibrium, on the point of moving down the plane
	m = 6.78 or M = 12.2	**M1**		For solving either
	6.78 ⩽ mass ⩽ 12.2	**A1**	6	

49. 9709_w15_MS_42 Q: 1

	Answer	Mark		Partial Marks
(i)		**M1**		For resolving forces in the x direction
	15 + Fcos60° = Fcos30°	**A1**		
	F = 41.0	**A1**	3	**AG** $F = 15(1 + \sqrt{3})$
(ii)	[$G = F$ (sin30° + sin60°)]	**M1**		For resolving forces in the y direction
	G = 56.0	**A1**	2	Allow $15(2 + \sqrt{3})$

50. 9709_w15_MS_43 Q: 1

	Answer	Mark		Partial Marks
	Tension is 30 N	B1		
	$[R = (4g - 30) \times 0.8]$	M1		For resolving forces acting on B, perpendicular to the plane.
	Normal component is 8 N	A1	3	

51. 9709_w15_MS_43 Q: 2

	Answer	Mark		Partial Marks
	$F = T\cos\alpha = 0.96T$	B1		
	$R = 0.2g - T\sin\alpha = 2 - 0.28T$	B1		
	$[0.96T = 0.25(2 - 0.28T)]$	M1		For using $F = \mu R$
	$[(0.96 + 0.07)T = 0.5 \rightarrow T = ...]$	M1		For solving resultant equation for T
	$T = 0.485$	A1	5	

52. 9709_w15_MS_43 Q: 3

	Answer	Mark		Partial Marks
		M1		For resolving forces in the x or $-x$ direction
	$120\cos75° = 150 - 100 - P\cos\theta°$	A1		
		M1		For resolving forces in the y direction
	$120\sin75° = P\sin\theta°$	A1		
	$[P^2 = 14400 - 12000\cos75° + 2500]$ or $\tan\theta = [120\sin75°/(50 - 120\cos75°)]$	M1		For using $P^2 = (P\cos\theta)^2 + (P\sin\theta)^2$ or for using $P\sin\theta / P\cos\theta = \tan\theta$
	$P = 117$ or $\theta = 80.7$	A1		
	$\theta = 80.7$ or $P = 117$	B1	7	

53. 9709_s20_MS_41 Q: 3

(a)	$0 = 5^2 - 2gs$	**M1**
	$s = 1.25$	**A1**
	[Height above ground =] 4.05 m	**A1**
		3
(b)	Use of $s = ut + ½ at^2$	**M1**
	$0.8 = 5t - 5t^2$	**A1**
	$t = 0.2$ or 0.8	**M1**
	Length of time = 0.6 s	**A1**
		4

54. 9709_s20_MS_41 Q: 4

(a)	Resolving forces in either direction	**M1**
	$R = T\sin30 + 0.1g$, $F = T\cos30$	**A1**
	$T\cos30 = 0.8\,(T\sin30 + 0.1g)$	**M1**
	$T = 1.72$ (1.7166...)	**A1**
		4
(b)	$R = 3\sin30 + 0.1g$	**B1**
	$3\cos30 - 0.8(3\sin30 + 0.1g) = 0.1a$	**M1**
	$a = 5.98$ ms^{-2} (5.9807...)	**A1**
		3

55. 9709_s20_MS_41 Q: 6

(a)	$\int k\left(t^2 - 10t + 21\right)\mathrm{d}t$	**M1**
	$s = k\left(\frac{1}{3}t^3 + 5t^2 + 21t\right) + \mathrm{C}$	**A1**
	$2.85 = k\left(\frac{1}{3}\times3^3 - 5\times3^2 + 21\times3\right) + \mathrm{C}$ or $2.4 = k\left(\frac{1}{3}\times6^3 - 5\times6^2 + 21\times6\right) + \mathrm{C}$	**M1**
	$2.85 = 27k + \mathrm{C}$, $2.4 = 18k + \mathrm{C}$ (A1 for both)	**A1**
	Solving for k	**M1**
	$k = 0.05$	**A1**
	$s = 0.05\left(\frac{1}{3}t^3 - 5t^2 + 21t\right) + 1.5$	**A1**
		7
(b)	Differentiating v or completing the square for v	**M1**
	$a = 0.05(2t - 10)$	**A1**
	Min value of v is at $t = 5$.	**M1**
	Displacement at $t = 5$ is 2.58 m (2.5833...)	**A1**
		4

56. 9709_s20_MS_42 Q: 1

(a)	Trapezium, deceleration steeper than acceleration	**B1**
	Time from 0 to 200	**B1**
		2
(b)	$0.5(170+200)v = 2775$	**M1**
	$v = 15$	**A1**
		2
(c)	$a = 15 \div 20$	**M1**
	$a = 0.75$	**A1**
		2

57. 9709_s20_MS_42 Q: 6

(a)	Correct for $0 \le t \le 5$	**B1**
	Correct for $5 \le t \le 7$	**B1**
	Correct for $7 \le t \le 13.5$	**B1**
		3
(b)	$a = -2t$ by differentiating	**M1**
	$a = -12$	**A1**
		2
(c)	$s = \int_0^5 (2t+1)\,dt + \int_5^6 (36-t^2)\,dt + \left\lvert \int_6^7 (36-t^2)\,dt + \int_7^{13.5} (2t-27)\,dt \right\rvert$	**M1**
	$s = \int_0^5 (2t+1)\,dt + \int_5^6 (36-t^2)\,dt + \left\lvert \int_6^7 (36-t^2)\,dt + \int_7^{13.5} (2t-27)\,dt \right\rvert$	**A1**
	$s = [t^2 + t] + [36t - \frac{t^3}{3}] + t^2 - 27t$	**M1**
	All correct	**A1**
	$s = 84.25$	**A1**
		5

58. 9709_s20_MS_43 Q: 4

(a)	Trapezium shape with gradient of right-hand side approximately 2 times left side	**B1**
		1
(b)	Constant velocity = 500/25 = 20 ms^{-1}	**B1**
	$20^2 = 0 + 2a \times 50$	**M1**
	$a = 4$	**A1**
		3
(c)	Time to accelerate = 20/4 = 5 s	**B1**
	Deceleration time = 2.5 s	**B1**
	So total time = 5 + 25 + 2.5 = 32.5 s	**B1**
		3

59. 9709_s20_MS_43 Q: 6

(a)	$a = 4 - t$ (**M1** for differentiation)	**M1**
	When $a = 0$, $t = 4$	**A1**
	At $t = 4$, $v = 12.5$	**A1**
		3
(b)	Velocity = 0 when $4.5 + 4t - 0.5t^2 = 0$	**M1**
	$t = 9$ (reject $t = -1$)	**A1**
	$\int (4.5 + 4t - 0.5t^2)dt$	**M1**
	$4.5t + 2t^2 - \frac{1}{6}t^3$ $[+c]$	**A1**
	Apply limits (0 and 9)	**M1**
	Distance = 81 m	**A1**
		6

60. 9709_W20_MS_41 Q: 4

	Answer	Mark	Partial Marks
	$[v = 3t^2 - 18t\ (+ C)]$	***M1**	Attempt to integrate a
	$[s = t^3 - 9t^2\ (+ C)]$	**#M1**	Attempt to integrate v
	$v = 3t^2 - 18t$ $s = t^3 - 9t^2$	**A1**	Both integrals correct
	$v = 0,\ 3t^2 - 18t = 0\quad [t = 6]$	***DM1**	Attempt to find t when $v = 0$
	$s = 6^3 - 9 \times 6^2 - [0]$	**#DM1**	Substitute limits correctly into s
	$s = 108$ m	**A1**	Answer must be positive
		6	

61. 9709_W20_MS_41 Q: 7

	Answer	Mark	Partial Marks
(a)	$0.2\times10\times0.5=\frac{1}{2}\times0.2\times v_B^2$	M1	Attempt PE or KE for motion from A to B
		M1	Attempt PE loss = KE gain from A to B
	$v_B^2=10$	A1	
	Alternative method for the first 3 marks		
	$0.2\times10\times\sin30=0.2a$, $a=5$	(M1)	Attempt to find acceleration a for motion from A to B
	$v_B^2=0^2+2\times5\times1$	(M1)	Use $v^2=u^2+2as$ in attempt to find speed at B
	$v_B^2=10$	(A1)	
(a)	**Alternative method for question 7(a)**		
	PE loss = $0.2\times10\times2\sin30=2$	M1	Attempt PE loss for motion from A to C
	KE gain $=\frac{1}{2}\times0.2\times v_C^2$	M1	Attempt KE gain for motion from A to C
	Both PE loss and KE gain correct	A1	
	$R=0.2\times10\times\cos30=\sqrt{3}$	B1	
	$F=\frac{\sqrt{3}}{2}\times0.2\times\frac{\sqrt{3}}{2}\times10=1.5$	M1	For using $F=\mu R$ where R must be a component of $0.2g$
	WD against $F=1.5\times1$	M1	Attempt WD against F
	$0.2\times10\times1=1.5\times1+\frac{1}{2}\times0.2\times v_C^2$	M1	Attempt work-energy equation for motion from A to C
	$v_c=\sqrt{5}=2.24\text{ ms}^{-1}$	A1	
		8	
(a)	**THEN, either this method for the next 5 marks**		
	$R=0.2\times10\times\cos30=\sqrt{3}$	B1	
	$F=\frac{\sqrt{3}}{2}\times0.2\times\frac{\sqrt{3}}{2}\times10=1.5$	M1	For using $F=\mu R$ where R must be a component of $0.2g$
	PE loss = $0.2\times10\times0.5=1$ WD against $F=1.5\times1$	M1	Attempt to find either PE loss or WD against F from B to C
	$\frac{1}{2}0.2\times10+0.2\times10\times0.5=1.5\times1+\frac{1}{2}0.2v_C^2$	M1	Apply work-energy equation for motion from B to C as KE at B + PE at B = WD against F + KE at C with $v_B\neq0$
	$v_c=\sqrt{5}=2.24\text{ ms}^{-1}$	A1	
	OR, this method for the next 5 marks		
	$R=0.2\times10\times\cos30=\sqrt{3}$	(B1)	
	$F=\frac{\sqrt{3}}{2}\times0.2\times\frac{\sqrt{3}}{2}\times10=1.5$	(M1)	For using $F=\mu R$ where R must be a component of $0.2g$
	$0.2\times10\sin30-1.5=0.2a \quad a=-2.5$	(M1)	Attempt to find acceleration a for motion from B to C
	$v_c^2=10+2\times-2.5\times1$	(M1)	Use $v^2=u^2+2as$ in attempt to find v_c using $v_B\neq0$
	$v_c=\sqrt{5}=2.24\text{ ms}^{-1}$	(A1)	
		8	

	Answer	Mark	Partial Marks
(b)	$0 = 10 + 2a$ [$a = -5$]	M1	Attempt to find a for motion from B to C, using $v_B^2 = 10$, $v_C = 0$
	$0.2 \times 10 \times \sin 30 - F = 0.2 \times -5$	M1	Attempt Newton's 2nd law for motion from B to C
	$2 = \mu\sqrt{3}$	M1	Use $F = \mu R$ where R is a component of $0.2g$ but $R = 0.2g$ is M0
	$\mu = \frac{2}{\sqrt{3}}$	A1	Any correct exact form such as $^2/_3\sqrt{3}$
	Alternative method for question 7(b)		
	PE loss $= 0.2 \times 10 \times 1 \sin 30 = 1$	M1	Attempt PE loss for motion from B to C
	$1 + ½ \times 0.2 \times 10 = F \times 1$	M1	Work-Energy equation for motion from B to C in the form PE at B + KE at B = WD against F using $v_B^2 = 10$, $v_C = 0$
	$F = \mu\sqrt{3}$	M1	Use $F = \mu R$ leading to an equation in μ where R is a component of $0.2g$
	$\mu = \frac{2}{\sqrt{3}}$	A1	Any correct exact form such as $^2/_3\sqrt{3}$
(b)	**Alternative method for question 7(b)**		
	PE loss $= 0.2 \times 10 \times 2 \sin 30 = 2$	M1	Attempt PE loss for motion from A to C
	$2 = F \times 1$	M1	Work-Energy equation for motion from B to C
	$F = \mu\sqrt{3}$	M1	Use $F = \mu R$ leading to an equation in μ where R is a component of $0.2g$
	$\mu = \frac{2}{\sqrt{3}}$	A1	Any correct exact form such as $^2/_3\sqrt{3}$
		4	

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62. 9709_W20_MS_42 Q: 4

	Answer	Mark	Partial Marks
(a)	$\left[2 = \frac{20}{T}\right] \to T = 10$	B1	
		1	
(b)	Distance travelled before constant speed = $½ \times 10 \times 20 + ½ \times (20 + V) \times 5$ $½ \times 10 \times 20 + ½ \times (20 - V) \times 5 + 5V$ $[= 150 + 2.5V]$	B1 FT	May be implied if seen within total distance FT on T value from **4(a)**
	Distance travelled after constant speed $= 27.5V + ½ \times 5V$ [$= 30V$]	B1	May be implied if seen within total distance
	$½ \times 10 \times 20 + ½ \times (20 + V) \times 5$ $= ⅓ [½ \times 10 \times 20 + ½ \times (20 + V) \times 5 + 27.5V + ½ \times 5V]$	M1	For attempting to use $\frac{1}{2}$ or $\frac{1}{3}$ correctly and for obtaining an equation for V which includes all parts of the journey. or $½ \times 10 \times 20 + ½ \times (20 + V) \times 5 = ½ [27.5V + ½ \times 5V]$
	$V = 12$	A1	
		4	

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63. 9709_W20_MS_42 Q: 5

	Answer	Mark	Partial Marks
(a)	$40 - gt = 0$ [$t = 4$]	M1	Using $v = u + at$ with $u = 40$, $v = 0$ and $a = -g$ to find the time taken to reach the highest point.
	Time to top of building = $4 - ½(4) = 2$	A1	May see $t = 4 + 2 = 6$ for A1
	$h = 40 \times 2 - ½ \times 10 \times 2^2$ $h = 40 \times 6 - ½ \times 10 \times 6^2$	M1	Using $s = ut + ½ at^2$ with $u = 40$, $a = -g$ and $t = 2$ or $t = 6$ to set up an equation which enables the value of h, the height of the building, to be found.
	$h = 60$	A1	
	Alternative method for question 5(a)		
	$0 = 40^2 + 2 \times (-10) \times H$	M1	For using $v^2 = u^2 + 2as$ with $u = 40$, $v = 0$ and $a = -g$ in order to find H, the greatest height achieved
	$H = 80$	A1	
	$s = ½ \times 10 \times 2^2$	M1	Use either $s = vt - ½ at^2$ with $v = 0$, $a = -g$, $t = 2$ or use $s = ut + ½ at^2$ with $u = 0$, $a = g$, $t = 2$ to find the distance travelled either in the final 2 seconds going up or the first 2 seconds going down
	$s = 20$ and so $h = 80 - 20 = 60$	A1	
		4	
(b)	Height of first particle above ground = $40t - ½ \times 10t^2$	B1	
	Height of second particle above top of building = $20(t-1) - ½ \times 10 \times (t-1)^2$	B1	
	$60 + 20(t-1) - ½ \times 10 \times (t-1)^2 = 40t - ½ \times 10t^2$	M1	Set up an equation involving expressions for displacement to enable the time at which the particles reach the same height to be found.
	$t = 3.5$ seconds	A1	
	Alternative method for question 5(b)		
	$h_1 = 40 \times 1 - 5 \times 1^2$ [= 35] and $v_1 = 40 - 10 \times 1$ [= 30]	B1	Distance travelled **and** speed of first particle after 1 second
	$H_1 = 30T - 5 \times T^2$, $H_2 = 20T - 5 \times T^2$	B1	Distance travelled by both particles, T seconds after the second particle is projected.
	$30T - 5 \times T^2 = 20T - 5 \times T^2 + (60 - 35)$	M1	Set up an equation in T involving expressions for displacement to enable the time at which the particles are at the same height to be found.
	$T = 2.5$ and so time to meet = $2.5 + 1 = 3.5$ seconds	A1	
		4	

64. 9709_W20_MS_42 Q: 7

	Answer	Mark	Partial Marks
(a)	$\int 0.1t^{3/2}dt$	*M1	For integrating a
	$v = 0.04t^{5/2} + 1.72$	A1	
	$0.04t^{5/2} + 1.72 = 3$	DM1	For attempting to solve the equation $v = 3$, to obtain t
	$t = 4$	A1	
		4	
(b)	$\int\left(0.04t^{5/2} + 1.72\right)dt$ $[s = \frac{2}{175}t^{7/2} + 1.72t(+C')]$	*M1	For integrating v which itself has come from integration
	For using correct limits correctly	DM1	
	Displacement when $t = 2$ is 3.57 m	A1	
		3	

65. 9709_W20_MS_43 Q: 1

	Answer	Mark	Partial Marks
(a)	$v = 30$	B1	Use $v = u + at$ (or equivalent *suvat)* with $v = 0$, $a = -g$ and $t = 3$
		1	
(b)	$[0 = 30^2 + 2(-10)s]$	M1	Using $v^2 = u^2 + 2as$ with $a = -g$, $v = 0$ and u = value from **1(a)**, or equivalent *suvat* method
	Greatest height is 45 m	A1	
		2	

66. 9709_W20_MS_43 Q: 5

	Answer	Mark	Partial Marks
(a)	$4t^2 - 20t + 21 = (2t-3)(2t-7) = 0 \to t = \ldots$	**M1**	For setting $v = 0$ and attempting to solve $v = 0$
	$t = 1.5$ and $t = 3.5$	**A1**	
		2	
(b)	$a = 8t - 20$, $a(0) = \ldots$	**M1**	For using $a = dv/dt$ and evaluating for $t = 0$
	$a = -20$	**A1**	
		2	
(c)	$8t - 20 = 0$, $t = 2.5 \to v = \ldots$ or $v = (2t-5)^2 - 4$, $v_{min} = \ldots$	**M1**	For setting $a = 0$, attempting to solve for t and substituting to obtain v, or for attempting to complete the square on the expression for v
	$v_{min} = -4\ \text{ms}^{-1}$	**A1**	
		2	
(d)	$s = \int(4t^2 - 20t + 21)\,dt$	**M1**	For using $s = \int v\,dt$ and attempting integration
	$s = \frac{4}{3}t^3 - 10t^2 + 21t(+c)$	**A1**	Correct integration
	$\frac{49}{6} - \frac{27}{2}$	**M1**	Substitute their limits (1.5 and 3.5) into *their* integral
	Distance $= \frac{16}{3} = 5.33$ m	**A1**	
		4	

67. 9709_m19_MS_42 Q: 2

	Answer	Mark	Partial Marks
(i)	$[0 = 30^2 + 2(-g)s]$	**M1**	Using $v^2 = u^2 + 2as$ with $v = 0$, $u = 30$ and $a = -g$ For any complete method for finding maximum height s
	s = maximum height = 900/20 = 45 m	**A1**	**AG**
		2	
(ii)	$[33.75 = 30t - \frac{1}{2}gt^2]$	**M1**	Applying $s = ut + \frac{1}{2}at^2$ with $s = 33.75$, $u = 30$ and $a = -g$
	$[5t^2 - 30t + 33.75 = 0$ or $4t^2 - 24t + 27 = 0]$	**M1**	Solve a 3-term quadratic for t
	$t = 1.5$ (reject $t = 4.5$)	**A1**	
	$v = 30 - 1.5g = 15$	**B1ft**	Use $v = u + at$ with $u = 30$ and $t = 1.5$ ft on t value found
	Alternative method for question 2(ii)		
	$v^2 = 30^2 - 2g(33.75) = 225 \to v = 15$	**B1**	Use $v^2 = u^2 + 2as$ with $u = 30$, $a = -g$ and $s = 33.75$ to find v
	$[33.75 = \frac{1}{2}(30 + 15) \times t]$ or $[15 = 30 - 10t]$	**M1**	Use $s = \frac{1}{2}(u + v) \times t$ with $s = 33.75$, $u = 30$ and v as found. or Use $v = u - gt$ with $u = 30$ and v as found
		M1	Solve for t
	$t = 1.5$	**A1ft**	ft on v value found
		4	

68. 9709_m19_MS_42 Q: 5

	Answer	Mark	Partial Marks
(i)	Velocity at $t = 3$ is $3 \times 3 = 9$	B1	
	[½ × 3 × 9 + ½ (9 + 7) × 2 + ½ × 3 × 7]	M1	Attempt distance travelled in the first 8 seconds using Distance = area under graph.
	Distance = 40 m	A1	
		3	
(ii)	[32 = 40 + area of triangle]	M1	Use given displacement to set up equation for area of triangle or attempt to find distance or displacement from $t = 8$ to $t = 16$
	Area of triangle or displacement/distance = (–)8	A1	
	[Distance = ½ × 8 × V = (–)8]	M1	Set up an equation for the area of triangle involving V or use *suvat* equations to set up an equation involving V
	$V = -2$	A1	
		4	

69. 9709_m19_MS_42 Q: 6

	Answer	Mark	Partial Marks
(i)	$[\int\left(0.4t^3 - 4.8t^{\frac{1}{2}}\right) dt]$	M1	Attempt to integrate a
	$v = 0.1t^4 - 3.2t^{\frac{3}{2}}\ (+c)$	A1	
	$[v = 0 \rightarrow 0.1t^4 - 3.2t^{\frac{3}{2}} = 0]$	DM1	Attempt to solve $v = 0$, and reach the form $t^{a/b} = k$
	$[t^{\frac{5}{2}} = 32]$	M1	Attempt to solve an equation of the form $t^{a/b} = k$
	$t = 4$	A1	
	$a = 16\text{ m s}^{-2}$	B1	
		6	
(ii)	$[s = \int 0.1t^4 - 3.2t^{\frac{3}{2}}\ dt]$	M1	Attempt to integrate v
	Displacement = $\left[0.02t^5 - 1.28t^{\frac{5}{2}}\right]_0^5$	A1	Correct integration.
	Displacement = –9.05 m (–9.05417...)	A1	
		3	

70. 9709_s19_MS_41 Q: 2

	Answer	Mark	Partial Marks
(i)	[$0 = 25 - 10t$]	**M1**	Use of $v = u$ □ at with $u = 25$, $v = 0$ and $a = -g$ or other complete method for finding t to highest point
	$t = 2.5$	**A1**	
		3	
(ii)	[$20 = 25t - ½ gt^2$]	**M1**	Applying $s = ut + ½at^2$ with $s = 20$, $u = 25$
	[$t = 1$ and $t = 4$]	**M1**	Solve a 3-term quadratic for t, factorising or formula
	Required time = 4 – 1 = 3 seconds	**A1**	
	Alternative method for question 2(ii)		
	[$v^2 = 25^2$ □ 2 □ (-10) □ 20 $\rightarrow$ $v =$ □ 15]	**M1**	Using $v^2 = u^2 + 2as$ with $u = 25$, $s = 20$ and $a = -g$
	[$-15 = 15 - 10T$] or equivalent	**M1**	Use v at $s = 20$ to find the time, T, taken to reach the maximum height and to return to $s = 20$
	Required time = 1.5 □ 1.5 = 3 seconds	**A1**	
		3	
(iii)	Max height reached at 2.5 s, hence reaches h after 2 s $h - 3 = 25$ □ $2 - 5$ □ 2^2	**M1**	Using their t from 2(i) – 0.5 in $s = ut + ½at^2$ Allow finding h without taking note of the additional 3 m
	$h = 33$ m	**A1**	
	Alternative method for question 2(iii)		
	Maximum height = ½ □ (25 + 0) □ 2.5 [= 31.25] o.e. In 0.5 s it falls distance ½ □ 10 × 0.5^2 [= 1.25]	**M1**	For attempting to find both the maximum height and the distance fallen in 0.5 seconds
	$h = 31.25 - 1.25$ □ 3 = 33 m	**A1**	
		2	

71. 9709_s19_MS_41 Q: 5

	Answer	Mark	Partial Marks
(i)	$a = 2t - 8$	**M1**	Differentiate to find a
	$a = 0 \rightarrow t = 4$	**M1**	Set $a = 0$ and solve for t
	Minimum $v = -4$ ms^{-1}	**A1**	Full marks available for correct use of a v-t graph or correct use of "$t = -b/2a$"
	Alternative method for question 5(i)		
	$v = (t-4)^2 - 4$	**M1**	Attempt to complete the square for v
	$[t = 4]$	**M1**	Choose the t value which gives minimum v
	Minimum $v = -4$ ms^{-1}	**A1**	
		3	
(ii)	$v = 0$ when $(t-2)(t-6) = 0$	**M1**	Find values of t when $v = 0$, factorise or formula
	$t = 2$ or $t = 6$	**A1**	
	$[s = ⅓\,t^3 - 4t^2 + 12t\ (+c)]$	**M1**	Integrate v to find s
		A1	Correct integration
	$0 \le t \le 2$ $s_1 = 8/3 - 16 + 24 = 32/3$ $2 \le t \le 6$ $s_2 = (216/3 - 144$ □ $72) - (8/3 - 16$ □ $24) = -32/3$ $6 \le t \le 8$ $s_3 = (512/3 - 4$ □ 8^2 □ 12 □ $8) - (216/3 - 144$ □ $72) = 32/3$	**M1**	Attempt to find s_1, s_2 and s_3 Look for consideration of the need for 3 intervals Allow use of symmetry when finding s_1, and s_3
		A1	2 correct values of displacement
	Total distance = 32 m	**A1**	All correct
		7	

72. 9709_s19_MS_42 Q: 2

	Answer	Mark	Partial Marks
	Possible equations include: $t = 0$ to $t = 5$ $\rightarrow$ $80 = 5u + 12.5a$ $t = 0$ to $t = 8$ $\rightarrow$ $160 = 8u + 32a$ $t = 5$ to $t = 8$ $\rightarrow$ $80 = 3(u + 5a) + 4.5a$ i.e. $80 = 3u + 19.5a$	**M1**	Use the equation $s = ut + ½at^2$ to set up one equation in u and a or using speeds as u (at $t = 0$), $u + 5a$ (at $t = 5$), $u + 8a$ (at $t = 8$) and then apply $s = ½ \times (u + v) \times t$
	$80 = 5u + ½ \times a \times 5^2$ $\rightarrow$ $5u + 12.5a = 80$	**A1**	One correct equation in a and u
	$160 = 8u + 0.5a \times 8^2$ $\rightarrow$ $8u + 32a = 160$	**A1**	Second correct equation in a and u
		M1	Attempt to solve a pair of valid simultaneous equations for a or u
	$a = \frac{8}{3}$	**A1**	Allow $a = 2.67$
	$u = \frac{28}{3}$	**A1**	Allow $u = 9.33$
		6	

73. 9709_s19_MS_42 Q: 7

	Answer	Mark	Partial Marks
(i)	Straight line, reaching positive v-axis and positive t-axis (negative gradient)	B1	
	Quadratic (U shape, through (0,0) and cutting t-axis at $t < 5$)	B1	
	Fully correct graphs with correct labelling with $t = 3$, $t = 5$, $v = 10$, $v = 60$ seen	B1	
		3	
(ii)	$s = \int (10 - 2t)\,dt = 10t - t^2\ (+ c)$ or use area of a triangle ½ × 10 × 5 [= 25]	B1	Use either integration to find s for Q or use a correct formula to find the area under the relevant triangle
		M1	Use integration to find the displacement for P
	$s = \int (6t^2 - 18t)\,dt = 2t^3 - 9t^2\ (+c)$	A1	Correct integration for P (unsimplified)
	$s(P) = \left[2t^3 - 9t^2\right]_0^5 = 25$ or solve $10t - t^2 = 2t^3 - 9t^2$	B1	**Either** evaluation of $s(P)$ at $t = 5$ and show that at $t = 5$, $s(P) = s(Q) = 25$ **or** show that $t = 5$ is a solution of the cubic by solving **or** verify $t = 5$ is a solution of the cubic by substitution.
		4	
(iii)	Distance $PQ = \lvert s_P - s_Q \rvert = \pm(2t^3 - 8t^2 - 10t)$	M1	Find the distance between P and Q Allow either sign s_P and s_Q must have been found by integration
	Maximum s if $6t^2 - 16t - 10 = 0$	M1	Differentiate to obtain an equation in t and attempt to solve
	$t = 3.19$	A1	
	Maximum Distance $PQ = (-)48.4$ m	A1	
	Alternative method for question 7(iii)		
	$6t^2 - 18t = 10 - 2t$	M1	State that greatest distance between P and Q occurs when $v_P = v_Q$
	$6t^2 - 16t - 10 = 0$	M1	Rearrange and attempt to solve for t
	$t = 3.19$	A1	
	Maximum Distance $PQ = (-)48.4$ m	A1	
		4	

74. 9709_s19_MS_43 Q: 1

	Answer	Mark	Partial Marks
	Trapezium	B1	Includes (0,0) and (....,0)
	$(t = 0)$, $t = 5$, $t = 29$, $t = 35$	B1	Correct trapezium with key time values
	$v_{max} = 2.1 \times 5 = 10.5\ \text{ms}^{-1}$	B1	
	[½ × (24 + 35) × 10.5] or [½ × 5 × 10.5 + 24 × 10.5 + ½ × 6 × 10.5]	M1	Use of area property to find distance
	309.75 m or 310 m	A1	
		5	

75. 9709_s19_MS_43 Q: 6

	Answer	Mark	Partial Marks
(i)	$[v = 6t^2/2 - 12t + C]$ $v = 3t^2 - 12t + C$	*M1	Use of $v = \int a\,dt$
	$[s = 3t^3/3 - 12t^2/2 + Ct + D]$ $s = t^3 - 6t^2 + Ct + D$	*M1	Use of $s = \int v\,dt$
	$[5 = 1 - 6 + C + D$ $C + D = 10$ $1 = 27 - 54 + 3C + D$ $3C + D = 28$ $\rightarrow$ $C = \ldots\ldots, D = \ldots\ldots]$	DM1	Substitutes for s and t and solves equations. Dependent on both Ms.
	$s = t^3 - 6t^2 + 9t + 1$ or $p = 9, q = 1$	A1	
		4	
(ii)	$[v = 0, 3t^2 - 12t + 9 = 0 (t - 1)(t - 3) = 0 \rightarrow t = \ldots\ldots]$	M1	Solves $v = 0$ to find t values
	$t = 1$ or $t = 3$	A1	
		2	
(iii)	$[\int_0^1 v\,dt + \int_1^3 v\,dt + \int_3^4 v\,dt]$	M1	Attempts to use at least three t intervals
	[For $0 \leqslant t \leqslant 1$, $s = (1 - 6 + 9 + 1) - 1 = 4$]	M1	Evaluates s for one time interval
	[$0 \leqslant t \leqslant 1$, $s = (1 - 6 + 9 + 1) - 1 = \mathbf{4}$; $1 \leqslant t \leqslant 3$, $s = (27 - 54 + 27 + 1) -$ $5 = {}^{-}\mathbf{4}$ $3 \leqslant t \leqslant 4$, $s = (64 - 96 + 36 + 1) - 1 = \mathbf{4}$]	A1	Correctly finds all at least two distances (ignoring signs)
	Total distance is 12 m	A1	
		4	

76. 9709_w19_MS_41 Q: 7

	Answer	Mark	Partial Marks
(i)	$0.6t^2 - 0.12t^3 = 0$	M1	For attempting to solve $v = 0$
	$(t = 0$ or$)$ $t = 5$	A1	
	$\int v\,dt = 0.2t^3 - 0.03t^4$	*M1	For integrating the velocity
	$OP = [0.2 \times 5^3 - 0.03 \times 5^4] - [0]$	DM1	Use limits to find OP
	Distance = 6.25 m	A1	AG
		5	
(ii)	$k \times 5^3 + c \times 5^5 = 6.25$	B1	Using $s = 6.25$ at $t = 5$ to set up equation in k and c
	$v = 3kt^2 + 5ct^4$	*M1	For differentiating s to find v
	$1.25 = 3k \times 5^2 + 5c \times 5^4$	DM1	For using the given value of $v = 1.25$ in the expression for v
	$125k + 3125c = 6.25$ $75k + 3125c = 1.25$	M1	For attempting to solve a pair of simultaneous equations in k and c and finding a value of either k or c
	$k = 0.1$, $c = -0.002$	A1	
		5	
(iii)	$a = 0.6t - 0.04t^3$	M1	For differentiating their expression for v
	At $t = 5$, $a = -2$ Acceleration $= -2$ ms^{-2}	A1	
		2	

77. 9709_w19_MS_42 Q: 1

	Answer	Mark	Partial Marks
	$(v =)\ 3t^2 - 12t + 4$	*M1	Attempt at differentiation of s to find v
	$(a =)\ 6t - 12$	*M1	Attempt at differentiation of v to find a
	[When $a = 0$, $t = 2$]	DM1	Solve to find t when $a = 0$ and find v at this time
	$v = -8\ \text{ms}^{-1}$	A1	
	Alternative method for question 1		
	$(v =)\ 3t^2 - 12t + 4$	M1	Attempt at differentiation of s to find v
	$(v =)\ 3(t-2)^2 - 8$ or $t = \frac{-b}{2a} = \frac{12}{6} = 2$	M1	For using the method of completing the square or using the value of '$\frac{-b}{2a}$' to find the t value of the minimum velocity
		M1	Use of the t value at minimum velocity to find v
	$v = -8\ \text{ms}^{-1}$	A1	
		4	

78. 9709_w19_MS_42 Q: 2

	Answer	Mark	Partial Marks
(i)	$\frac{(12-V)}{(35-30)} = 0.8$ or $12 = V + 0.8 \times 5$	M1	Use gradient of graph or constant acceleration formulae to set up an equation in V
	$V = 8$	A1	
		2	
(ii)	$\left[25 \times 8 + 5 \times 10 + 15 \times 6 + \frac{1}{2} \times (U+8) \times 5 = 375\right]$	M1	Attempt to find total distance travelled by the tractor in 50s to set up an equation for U using EITHER areas OR suvat equations OR a combination of areas and suvat In either case total distance must be attempted
		A1FT	Correct equation FT on *their* V from **(i)**
	$U = 6$	A1	
		3	

79. 9709_w19_MS_42 Q: 5

	Answer	Mark	Partial Marks
(i)	$h_A = 20t - \frac{1}{2}\times 10t^2$ or $h_B = \pm\frac{1}{2}\times 10(t-1)^2$	B1	OE $h_A = 20(T+1) - \frac{1}{2}\times 10(T+1)^2$ or $h_B = \pm\frac{1}{2}\times 10T^2$
	[Meet when $20t - \frac{1}{2}\times 10t^2 + \frac{1}{2}\times 10(t-1)^2 = 40$]	*M1	Set up an equation using *their* h_A, *their* h_B and 40
	$10t - 35 = 0$	DM1	Solve for t and attempt to find the height at collision.
	$t = 3.5$ so height at collision = 8.75 m	A1	$T = 2.5$ and height at collision = 8.75 m
	Alternative method for question 5(i)		
	$h_A = 20\times 1 - \frac{1}{2}\times 10\times 1^2 = 15, v = 20 - 10\times 1 = 10$	B1	Finding distance travelled by A and its speed after 1 second
	$H_A + H_B = 25$ $\left(10T - \frac{1}{2}\times 10\times T^2\right) + \frac{1}{2}\times 10\times T^2 = 25$	*M1	T is the time beyond 1s until the particles reach same level H_A and H_B are distances travelled by A and B in T seconds.
	[$10T = 25 \to T = 2.5$]	DM1	Solve for T and attempt to find the height at collision
	$t = 3.5$ so height = 8.75 m	A1	
		4	
(ii)	$v_A = 20 - gt = -15$ **or** $v_A{}^2 = 20^2 + 2(-g)(8.75)$	M1	Use of *their* t or *their* $h \leqslant 20$ from **5(i)** in a constant acceleration formula which would lead to finding v_A
	$v_B = -g(t-1) = -25$ **or** $v_B{}^2 = 2(g)(40 - 8.75)$	M1	Use of *their* $t \pm 1$ or *their* $40 - h$ from **5(i)** in a constant acceleration formula which would lead to finding v_B
	Difference = 10 ms^{-1}	A1	CWO
		3	

80. 9709_w19_MS_43 Q: 4

	Answer	Mark	Partial Marks
(i)	$s_{PQ} = 20\times 10 - 0.5a\times 10^2$ **or** $s_{QR} = 20\times 10 + 0.5a\times 10^2$	M1	For use of $s = vt - \frac{1}{2}at^2$ or $s = ut + \frac{1}{2}at^2$ OE suvat to find PQ or QR
	$s = 200 - 50a$ **and** $1.5s = 200 + 50a$	A1	OE
	$1.5(200 - 50a) = 200 + 50a \rightarrow 100 = 125a \rightarrow a = 0.8$ ms^{-2}	B1	AG
		3	
(ii)	Distance $QS = 20\times 20 + \frac{1}{2}\times 0.8\times 20^2$	M1	Using $s = ut + \frac{1}{2}at^2$
	Distance=560 m	A1	
	Average speed between Q and $S = \frac{560}{20} = 28$ ms^{-1}	B1	
		3	

81. 9709_w19_MS_43 Q: 6

	Answer	Mark	Partial Marks
(i)	$10 = 0.04\times5^3 + 5^2c + 5k$ $\quad (5c + k = 1)$	B1	Use of t=5, v=10
	$s = \frac{0.04}{4}t^4 + \frac{ct^3}{3} + \frac{kt^2}{2} + (C)$	*M1	For use of $s = \int v\mathrm{d}t$
	$25 = 0.01\times5^4 + \frac{5^3}{3}c + \frac{5^2}{2}k$	DM1	Use of $t = 0$, s = 0 and $t = 5$, $s = 25$
	$6.25 + \frac{125}{3}c + \frac{25}{2}k = 25$ $\quad \left(\frac{125}{3}c + \frac{25}{2}k = 18.75\right)$	A1	
	Solving for c or for k	M1	
	$c = -0.3$ and $k = 2.5$	A1	
		6	
(ii)	$a = 0.12t^2 - 0.6t + 2.5$	M1	For use of $a = \frac{\mathrm{d}v}{\mathrm{d}t}$
	$a' = 0.24t - 0.6 = 0 \to t = ...$ **or** $a = 0.12(t^2 - 5t + ...) = 0.12\left[(t-2.5)^2 + ...\right]$	M1	Uses $\frac{\mathrm{d}a}{\mathrm{d}t} = 0$ or completes the square for a
	Minimum when $t = 2.5$	A1	AG
		3	

82. 9709_m18_MS_42 Q: 5

	Answer	Mark	Partial Marks
(i)	$200 = \frac{1}{2} \times (0 + v) \times 10$	M1	Use of *suvat*
	$v = 40\text{ m s}^{-1}$	A1	AG
	$200 = \frac{1}{2} \times a \times 10^2$	M1	Second use of *suvat*
	$a = 4\text{ m s}^{-2}$	A1	
		4	
(ii)	$0 = 40^2 - 2 \times g \times s$	M1	Use of *suvat* with $a = g$
	$s = 80$ so height above ground = 280 m	A1	
		2	
(iii)	*EITHER:* $0 = 40 - gt_1$	(M1	Use of *suvat* to find extra time to highest point
	$t_1 = 4$	A1	
	$280 = \frac{1}{2}gt_2^2$	M1	Use of *suvat* to find time from highest point to ground
	$t_2 = \sqrt{56} = 7.48...$ so total time = 21.5 s	A1)	
	OR: $-200 = 40t_3 - \frac{1}{2}gt_3^2$	(M1	Use of $s = ut + \frac{1}{2}at^2$ with 200, 40 and g used
	$5t_3^2 - 40t_3 - 200 = 0$ o.e. $[t_3^2 - 8t_3 - 40 = 0]$	A1	Correct quadratic for time under gravity
	$[t_3 = 4 \pm \sqrt{56} = 4 \pm 7.48]$	M1	Solution of relevant 3-term quadratic
	$t_3 = 11.48$ so total time is 21.5 s	A1)	
		4	

83. 9709_m18_MS_42 Q: 7

	Answer	Mark	Partial Marks
(i)	0.2 (m s^{-2})	**B1**	
		1	
(ii)	$a = -1600t^{-3}$	**M1**	For attempted differentiation of $-2 + \dfrac{800}{t^2}$
	Acceleration at $t = 20$ is –0.2 (m s^{-2})	**A1**	
		2	
(iii)	Straight line joining $t = 0$, $v = 4$ to $t = 10$, $v = 6$	**B1**	
	Curve with correct concavity joining end of line to $t = 20$, $v = 0$	**B1**	
	Correct labelling on axes provided the curves pass through (0,4), (10,6), (20,0)	**B1**	
		3	
(iv)	Trapezium area = 50	**B1**	or from integration of $4 + 0.2t$
	$\int\left(-2 + 800t^{-2}\right)dt = -2t - 800t^{-1}$	**M1**	Integration attempted
		A1	Correct indefinite integral
	$\left[-2t - 800t^{-1}\right]_{10}^{20}$ $= -40 - 40 + 20 + 80$	**M1**	Correct use of the limits $t = 10$ and $t = 20$
	Distance is 50 + 20 = 70 m	**A1**	Correct total
		5	

84. 9709_s18_MS_41 Q: 1

	Answer	Mark	Partial Marks
	$-5 = 24t - 5t^2$	M1	Use $s = ut + \frac{1}{2}at^2$
	$5t^2 - 24t - 5 = 0$	M1	Solve relevant 3 term quadratic
	$t = 5$	A1	
		3	
	Alternative scheme for Question 1		
	$0 = 24 - 10t_1 \rightarrow t_1 = 2.4$	M1	Attempt to find the time taken to reach the highest point
	$0 = 24^2 + 2 \times (-10) \times h \rightarrow h = 28.8$ And $33.8 = \frac{1}{2}gt_2^2 \rightarrow t_2 = 2.6$	M1	Find total height h reached and attempt to find time taken from highest point to ground level
	$t = t_1 + t_2 = 5$	A1	

85. 9709_s18_MS_41 Q: 4

	Answer	Mark	Partial Marks
(i)		M1	Attempt differentiation
	$v = 3t^2 - 8t + 4$	A1	
		2	
(ii)	$3t^2 - 8t + 4 = 0$	M1	Set $v = 0$ and attempt to solve a relevant 3 term quadratic
	$t = \frac{2}{3}$ and $t = 2$	A1	
		2	
(iii)	$[6t - 8 = 0]$	M1	Differentiate v and equate to 0
	$[t = \frac{4}{3}, v = 3(\frac{4}{3})^2 - 8(\frac{4}{3}) + 4]$	M1	Solve for t and attempt v
	$v = -\frac{4}{3}$	A1	
		3	
	Alternative scheme for Question 4(iii)		
	$[v = 3(t^2 - \frac{8}{3}t) + 4 = 3(t - \frac{4}{3})^2 + ...]$	M1	Attempt to complete the square for v
	$[t = \frac{4}{3}, v = 3(t - \frac{4}{3})^2 - \frac{4}{3}]$	M1	Find value of t for minimum v and attempt to find v
	$v = -\frac{4}{3}$	A1	

86. 9709_s18_MS_41 Q: 5

	Answer	Mark	Partial Marks
(i)	$[s_1 = \frac{1}{2}(0+12)\times 6]$	M1	Use constant acceleration equations or find area in (t,v) graph to find the distance s_1 travelled in the first 6 seconds
	$[s_2 = 10 \times 12]$	M1	Use constant acceleration equations or find area in (t,v) graph to find s_2 the distance travelled between 6s and 16s
	Distance for first 16 s is $36 + 10 \times 12 = 156$	A1	
	Curve concave up for $0 < t < 6$ starting at (0 , 0) ending at (6 , 36)	B1	Co-ordinates refer to (t,s) in a displacement-time graph
	Line, positive gradient, $6 < t < 16$ starts at (6 , 36) ends at (16 , 156)	B1	
	Curve concave down, $16 < t < 20$ from (16 , 156) to (20 , 200)	B1	
		6	
(ii)	$[44 = \frac{1}{2}(12+V)\times 4]$	M1	Use relevant constant acceleration equations or the area property of a v–t graph
	$V = 10$	A1	
		2	

87. 9709_s18_MS_42 Q: 4

	Answer	Mark	Partial Marks
(i)	For example $100 = 4u + 8a$ or $100 = \frac{1}{2}(u + v) \times 4$ or $148 = 4v + 8a$ or any equation in two of the variables u, v, w, a	M1	Any relevant use of constant acceleration equations in any two of the variables below a is acceleration u is speed at A v is speed at B w is speed at C
		A1	One correct equation
	For example $248 = 8u + 32a$ or two further correct equations in 3 unknowns such as $148 = 4v + 8a$ **and** $v = u + 4a$ or $148 = \frac{1}{2}(v + w) \times 4$ and $248 = \frac{1}{2}(u + w) \times 8$	A1	A second correct equation in the same two variables or two further correct equations leading to three equations in three of the unknowns u, v, w, a
		M1	Attempt to solve for a or u This must reach $a = \ldots$ or $u = \ldots$
	$a = 3$	A1	AG
	$u = 19$	B1	
		6	
(ii)	$61^2 = 19^2 + 2 \times 3 \times s$	M1	Attempt equation for $s = AD$
	$[s = 560 \rightarrow CD = 560 - 248]$	M1	Attempt to find CD
	Distance CD is 312	A1	
		3	
	Alternative method for 4(ii)		
	Speed at C is $19 + 8 \times 3$ [= 43]	M1	Attempt to find speed at C
	$\left[61^2 = 43^2 + 2 \times 3 \times CD\right]$	M1	Attempt to find CD
	Distance CD is 312	A1	

88. 9709_s18_MS_42 Q: 6

	Answer	Mark	Partial Marks
(i)		M1	Attempt to integrate a
	$v = 6t - 0.12t^2$ $(+ c)$	A1	
	$0 = 6 \times 20 - 0.12 \times 20^2 + c$	DM1	Substitute $v = 0$, $t = 20$ in an equation with arbitrary constant
	$0.12t^2 - 6t + 72 = 0$	DM1	Substitute $v = 0$ and attempt to solve a 3-term quadratic
	$t = 30$	A1	
		5	
6(ii)	$s = 3t^2 - 0.04t^3 - 72t$ $(+ k)$	M1	Attempt to integrate v
	$s(30) - s(20) = -540 - (-560)$	DM1	Use of limits 20 and their 30
	Distance travelled = 20	A1	
		3	

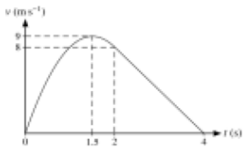
89. 9709_s18_MS_43 Q: 1

	Answer	Mark	Partial Marks
(i)	0.4 (m s^{-2})	B1	
	Total:	1	
(ii)	$[9040 = \frac{1}{2}(600 + T) \times 16]$	M1	Equating area of the trapezium to the total distance or using $s = ½ (u + v)t$ or equivalent
	Time is 530 (s)	A1	
	Total:	2	
(iii)	$[s = \frac{1}{2} \times (600 - 530 - 40) \times 16]$	M1	Use of triangular area, or equivalent
	Distance is 240 (m)	A1	
	Total:	2	

90. 9709_s18_MS_43 Q: 2

	Answer	Mark	Partial Marks
	$[V^2 = 5^2 + 2 \times g \times 7.2]$	M1	Use of *uvast* to find V
	$V = 13$	A1	
	$[13 = 5 + gt \quad t = ...]$ 0.8 (s)	M1	Use of *uvast* to find time for A to reach ground
	$[0 = 6.5 - gt \quad t = ...]$ 0.65 (s)	M1	Use of *uvast* to find time from ground to B
	Total time is 1.45 (s)	A1	
	Total:	5	

91. 9709_s18_MS_43 Q: 7

	Answer	Mark	Partial Marks
(i)	$[\frac{dv}{dt} = 12 - 8t]$ or e.g. $[-4[(t-1.5)^2 - 2.25]]$	M1	For attempted differentiation of $12t - 4t^2$ (or for alternative e.g. completing the square)
	[Maximum v when $t = 1.5 \Rightarrow v = 12 \times 1.5 - 4 \times 1.5^2$]	M1	For finding and using t
	Maximum velocity is 9 (m s^{-1})	A1	
	Total:	3	
(ii)	$[\frac{dv}{dt} = 12 - 8t = -4]$	M1	Finding acceleration for $0 \leqslant t \leqslant 2$ when t = 2
	Acceleration for $2 \leqslant t \leqslant 4$ is –4 No instantaneous change	A1	Both values correct, with correct statement
	Total:	2	
(iii)		B1	Quadratic shape (with max) for $0 \leqslant t \leqslant 2$
		B1	Line with negative gradient from (2, …) to (4,0)
		B1	All correct, smooth join and key values indicated
	Total:	3	
(iv)	Area of triangle is 8	B1	(May be obtained by integrating $16 - 4t$ or use of *uvast*)
	$[\int (12t - 4t^2)\,dt = 6t^2 - \frac{4}{3}t^3]$	M1	Integration attempt for $0 \leqslant t \leqslant 2$
	$[6 \times 2^2 - \frac{4}{3} \times 2^3 - 6 \times 0^2 + \frac{4}{3} \times 0^3]$	DM1	Use of limits 0 and 2; condone absence of zero terms
	Area under curve is $\frac{40}{3}$ or 13.3	A1	
	Distance travelled is $\frac{64}{3}$ (m) or 21.3 (m)	A1	
	Total:	5	

92. 9709_w18_MS_41 Q: 7

	Answer	Mark	Partial Marks
(i)	$v=\int(5.4-1.62t)\,dt$	M1	For using integration of a to find v
	$v=5.4t-0.81t^2\,(+C)$	A1	
	$5.4t-0.81t^2=0$	M1	For solving $v=0$
	$t=6\frac{2}{3}=\frac{20}{3}\,s$	A1	
		4	
(ii)	$v(10)=-27\text{ ms}^{-1}$	B1	
	Inverted parabola	B1	
	$v=0$ at $t=0$, negative at $t=10$ and through $\left(6\frac{2}{3},0\right)$	B1	
		3	
(iii)	$s=\int(5.4t-0.81t^2)\,dt$	M1	For using integration of v to find s
	$s=2.7t^2-0.27t^3\,(+C)$	A1	
	At $t=6\frac{2}{3}$, displacement $=40$	M1	For evaluating the integral at the time when $v=0$
	At $t=10$ displacement $=0$	M1	For evaluating the integral at time $t=10$
	Total distance $=80$ m	A1	
		5	

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93. 9709_w18_MS_42 Q: 3

	Answer	Mark	Partial Marks
(i)	Acceleration $=-1\text{ m s}^{-2}$	B1	Allow deceleration $=1\text{ m s}^{-2}$
		1	
(ii)	$[V/4=1$ or $(V+2)/6=1]$	M1	Use of gradient of line between $t=4$ and $t=10$ or use of similar triangles to find V
	$V=4$	A1	
		2	
(iii)	[Distance = Area = ½ (6 + 2) × 2 = 8]	M1	Attempt distance travelled in first 6 seconds
	Distance $AB=3\times 8=24$ m	A1	
	$[\frac{1}{2}\times(T-6)\times 4=24]$	M1	Attempt to find the distance travelled from $t=6$ to $t=T$ and set up an equation for T
	$T=18$	A1	
		4	

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94. 9709_w18_MS_42 Q: 5

	Answer	Mark	Partial Marks
(i)	$[1.2T^{1/2} - 0.6T = 0]$	**M1**	Attempt to find time of maximum v, set $a = 0$ and solve for T
	$T^{1/2} = 2 \to T = 4$	**A1**	
		2	
(ii)	$[da/dt = 0.6t^{1/2} - 0.6]$	**M1**	Attempt to differentiate a
	$t = 1$	**A1**	Solve $da/dt = 0$ and find t
	$[v = 0.8t^{3/2} - 0.3t^2 (+ C)]$	**M1**	Attempt to integrate a to find v
		A1	Correct integration
	$[C = 1]$	**M1**	Use $v = 1$ at $t = 0$ either finding C or by using limits as $v(1) - v(0) = [0.8(1)^{3/2} - 0.3(1)^2] - [0.8(0)^{3/2} - 0.3(0)^2]$
	Velocity when acceleration is max is 1.5 ms^{-1}	**A1**	$v = 1.5$
		6	

95. 9709_w18_MS_43 Q: 4

	Answer	Mark	Partial Marks
(i)		**B1**	Three correct straight lines
	$v = 6 \text{ m s}^{-1}$, $t = 5$ s and $t = 17$ s	**B1**	Correct trapezium with key values
	$[½ \times 6 \times (12 + 20)]$ or $[½ \times 5 \times 6 + 12 \times 6 + ½ \times 3 \times 6]$	**M1**	Use of trapezium area or use of suvat formulae
	Total distance = 96 m	**A1**	**AG**
		4	
(ii)	$[½ \times 20 \times v = 96]$	**M1**	Uses area of triangle = 96 or uses $s = ut + ½ at^2$ to form equation in a
	$v = 9.6 \text{ m s}^{-1}$ or $48 = ½ a (10)^2$	**A1**	
	Acceleration = 9.6 / 10 = 0.96 m s^{-2}	**A1**	
		3	

96. 9709_w18_MS_43 Q: 7

	Answer	Mark	Partial Marks
(i)	Acceleration = 0 when $t = 5$ from $25 - t^2 = 0$	B1	
	$[v = 25t - ⅓t^3]$	M1	Use of integration
	[Max speed $= 25 \times 5 - ⅓ \times 5^3$]	M1	Substitution for t
	Max speed $= 83⅓$ m s^{-1}	A1	
		4	
(ii)	$[s = 12½t^2 - {}^1/_{12}t^4]$	M1	Use of integration
	Distance = 260 m (260.4166…)	A1	
		2	
(iii)	At $t = 9$, $v = 25 \times 9 - ⅓ \times 9^3 = -18$	B1ft	ft v from **(i)**
	$\left[\, s = \int_9^{25}\left(-3t^{-\frac{1}{2}}\right)dt = \left[-6t^{\frac{1}{2}}\right]\right]$	M1	Use of integration
	[Change in velocity from $t = 9$ to $t = 25 = \left[-6t^{\frac{1}{2}}\right] = -6 \times 5 + 6\times 3 = -12$]	M1	Substituting limits
	Velocity at $t = 25$ is $-18 - 12 = -30$ m s^{-1}	A1	
		4	
	OR:		
(iii)	At $t = 9$, $v = 25 \times 9 - {}^1/_3 \times 9^3 = -18$	B1ft	ft v from **(i)**
	$[\, s = \int -3t^{-½}\, dt = -6t^{½}\ (+ C)]$	M1	Use of integration
	$[t = 9,\ v = -18 \rightarrow C = 0,\ t = 25,\ v = -6 \times 25^{½}\,]$	M1	Finds C and substitutes $t = 25$
	Velocity at $t = 25$ is -30 m s^{-1}	A1	
		4	

97. 9709_m17_MS_42 Q: 5

	Answer	Mark	Partial Marks
(i)	$0 = a + b \times 35^2$ $40 = a + b \times 15^2$	M1	For matching velocities at $t = 15$ and using $v = 0$ at $t = 35$
	$[1000b = -40 \rightarrow b = -0.04]$ $[a = 0.04 \times 352 = 49]$	M1	Solve for a and b
	$a = 49$ and $b = -0.04$ **AG**	A1	
	Total:	**3**	
(ii)	$0 \leqslant t \leqslant 5$ correct	B1	Increasing quadratic, from (0,0) to (5,20), concave up
	$5 \leqslant t \leqslant 15$ correct	B1	Line from (5,20) to (15,40)
	$15 \leqslant t \leqslant 35$ correct	B1	Decreasing quadratic, from (15,40) to (35,0), concave down
	20 and 40 seen correct on v-axis	B1	
	Total:	**4**	
(iii)	$A_1 = \int_0^5 0.8t^2 \mathrm{d}t = \frac{100}{3}$	B1	
	$A_2 = \frac{1}{2}(20+40) \times 10 = 300$	M1	Using trapezium rule or integration for $t = 5$ to $t = 15$
	$A_3 = \int_{15}^{35} (a + bt^2) \mathrm{d}t$ $= 49t - \frac{0.04}{3}t^3$	M1	Attempt to integrate the quadratic function from $t = 15$ to $t = 35$
	$A_3 = 453.3333 = 1360/3$	A1	
	Total Distance = 2360/3 = 787 m	A1	
	Total:	**5**	

98. 9709_s17_MS_41 Q: 5

	Answer	Mark	Partial Marks
(i)	$[12^2 = 20^2 - 2a \times AB$ $6^2 = 12^2 - 2a \times BC]$	M1	Use $v^2 = u^2 + 2(-a)s$ for AB or BC where a is the deceleration
	$AB = 128/a$	A1	
	$BC = 54/a$	A1	
	$AB : BC = 64:27$	A1	Allow equivalent unsimplified ratio
	Total:	4	
(ii)	$0 = 20^2 - 2a \times 80 \rightarrow a = 2.5$	M1	Use $v^2 = u^2 + 2(-a)AD$ to find a
	$BC = 54/2.5$	M1	Use a to find BC
	$BC = 21.6$ m	A1	
	Total:	3	

99. 9709_s17_MS_41 Q: 6

	Answer	Mark	Partial Marks
(i)	$[q + r = 4$ and $2q + 4r = 4]$	M1	Use $v = 4$ at $t = 1$ and $t = 2$
	$q = 6$ and $r = -2$ so $v = 6t - 2t^2$	A1	
	$a = 6 - 4t$	M1	Differentiation used for a
	At $t = 0.5$, $a = 4$	A1	AG
	Total:	4	
(ii)	$v = 6t - 2t^2 = 0$	M1	Set $v = 0$ and solve for t
	$t = 0$ and $t = 3$	A1	
	Total:	2	
(iii)	*EITHER*: $s = \int(6t - 2t^2)\,dt$	(M1	Attempt to integrate v to find s
	$s = 3t^2 - \frac{2}{3}t^3 + C$	A1	
	$0 = 3 \times 3^2 - \frac{2}{3} \times 3^3 + C$	M1	Use $s = 0$ when $t = 3$ to find C
	$C = -9$ so distance = 9 m	A1)	Valid argument
	OR: $s = \int_0^3 (6t - 2t^2)\,dt$	(M1	Attempt integration with limits
	$\left[3t^2 - \frac{2}{3}t^3\right]_0^3$	A1	Correct integration and correct limits but no evaluation
	$[27 - 18 = 9]$	M1	Evaluation of integral between limits
	Distance from O at $t = 0$ is 9 m	A1)	With explanation
	Total:	4	

100. 9709_s17_MS_42 Q: 3

	Answer	Mark	Partial Marks
(i)		M1	Attempt s_A as $s_A = k + 10t$ (any k)
	$s_A = 20 + 10t$	A1	
	$s_B = 16t + ½(–2)t^2$ [$= 16t – t^2$]	B1 FT	Allow FT only if $s_A = 10t$ and $s_B = 16(t – 2) + ½(–2)(t – 2)^2$ i.e. t measured from when A passes O
	Total:	3	
(ii)	$v_B = 16 – 2t \to v_B = 0,\ t = 8$	B1	
	$s = s_A – s_B$ [$= 20 + 10t + t^2 – 16t = t^2 – 6t + 20$]	M1	Finding distance between A and B at time $t = T$ ($T > 0$) found from a valid method for $v_B = 0$
	$t = 8,\ s = 36$ (m)	A1	
	Total:	3	
(iii)	$\frac{ds}{dt} = 2t – 6$ **or** $s = t^2 – 6t + 20 = (t – 3)^2 + 11$	M1	Either use differentiation or complete the square, or state value of t when speeds are the same
	[$t = 3$]	M1	Solve for t and evaluate $s_A – s_B$ at this value of t
	$s = s_A – s_B = 11$ m	A1	
	Total:	3	

101. 9709_s17_MS_43 Q: 3

	Answer	Mark	Partial Marks
(i)	Trapezium, right-hand steeper than left-hand slope	B1	
	Total:	1	
(ii)	Deceleration 0.5 T	B1	May be implied
	Constant speed 180 – 1.5 T	B1	
	Total:	2	
(iii)	$0.5[180 + (180 – 1.5T)] \times 25 = 3300$	M1	Uses area property
	$T = 64$	A1	
	Distance decelerating = [$0.5 \times 32 \times 25 =$] 400 m	B1	
	Total:	3	

102. 9709_s17_MS_43 Q: 4

	Answer	Mark	Partial Marks
(i)	$a = 3 \times 2 \times (2t-5)^2$ [= 54]	*M1	Uses a = dv/dt
	$6(2t-5)^2 = 54 \rightarrow t = \ldots$	DM1	Solves for t
	$t = 1, 4$	A1	
	Total:	3	
(ii)	$s = \dfrac{(2t-5)^4}{4 \times 2}$ (+ C)	*M1	Uses $s = \int v \, dt$
	$C = -\dfrac{625}{8}$	DM1	Uses $s = 0$ at $t = 0$
	$s = \dfrac{(2t-5)^4}{8} - \dfrac{625}{8}$	A1	
	Total:	3	
	Alternative method for Question 4		
(i)	$v = 8t^3 - 60t^2 + 150t - 125$ $\rightarrow a = 24t^2 - 120t + 150$	*M1	Uses a = dv/dt
	$24t^2 - 120t + 150 = 54 \rightarrow t = \ldots$	DM1	Solves for t
	$t = 1, 4$	A1	
	Total:	3	
(ii)	$s = \int 8t^3 - 60t^2 + 150t - 125 \, dt$ $\rightarrow s = \dfrac{8}{4}t^4 - \dfrac{60}{3}t^3 + \dfrac{150}{2}t^2 - 125t$ (+ C)	*M1	Uses $s = \int v \, dt$
	$C = 0$	DM1	Uses $s = 0$ at $t = 0$ (may be implied)
	$s = 2t^4 - 20t^3 + 75t^2 - 125t$	A1	
	Total:	3	

103. 9709_s17_MS_43 Q: 5

	Answer	Mark	Partial Marks
(i)	$s_2 = 20t - 0.5gt^2$	B1	Second particle
		M1	Uses $s = ut + ½at^2$ for first particle
	$s_1 = 12(t+2) - 0.5g(t+2)^2$	*A1	
	$12(t+2) - 0.5g(t+2)^2 = 20t - 0.5gt^2$ $\rightarrow t = \ldots$	DM1	Solves $s_1 = s_2$
	$t = \dfrac{1}{7} = 0.143$	A1	
	Total:	5	
(ii)	[$s = 20 \times \dfrac{1}{7} - 5 \times (\dfrac{1}{7})^2 = 2.755\ldots$] Height is 2.76 m	B1	
	Total:	1	

104. 9709_w17_MS_41 Q: 4

	Answer	Mark	Partial Marks
(i)	Acceleration $= \dfrac{(-25)}{2.5} = -10 \text{ m s}^{-2}$	**B1**	AG
		1	
(ii)	$V = -15 + 7.5 \times 4$	**M1**	Using v–t graph OE
	$V = 15 \text{ m s}^{-1}$	**A1**	
		2	
(iii)	Using $v = 0$ at $t = 4.5$ and $t = 8$	**B1**	
		M1	Attempting to use area to find total distance travelled
	$\frac{1}{2} \times (4.5 + 2) \times 10$ $+ \frac{1}{2} \times (8 - 4.5) \times 15$ $+ \frac{1}{2} \times (T - 8) \times 15 = 100$	**M1**	For setting up an equation for total distance travelled and solving for T
	$T = 13.5$	**A1**	
		4	

105. 9709_w17_MS_41 Q: 5

	Answer	Mark	Partial Marks
(i)	Acceleration = 0.4 m s^{-2}	**B1**	
		1	
(ii)	$\frac{100}{t^2} - 0.1t = 0$	**M1**	For setting $v = 0$ and solving for t
	$t = 10$ s	**A1**	
		2	
(iii)	Distance $t = 0$ to $t = 5$ is ½ (1.5 + 3.5) × 5 = 12.5	**B1**	Trapezium rule or integration
	$s(t) = \int\left(\frac{100}{t^2} - 0.1t\right)dt$	**M1**	For integration
	$= -\frac{100}{t} - 0.05t^2\ (+C)$	**A1**	Correct integration
	$s(10) - s(5)$	**M1**	Use limits 5 and 10 used or find + C
	Total distance = 12.5 + 6.25 = 18.75 m	**A1**	
		5	

106. 9709_w17_MS_42 Q: 3

	Answer	Mark	Partial Marks
(i)	$s_{AB} = 14 \times 5 + ½a \times 5^2$	**B1**	or $s_{AB} = ½(14 + 14 + 5a) \times 5$ OE
	$s_{AC} = 14 \times 8 + ½a \times 8^2$	**B1**	or $s_{AC} = ½(14 + 14 + 8a) \times 8$ OE
	$[112 + 32a = 2(70 + 12.5a)]$	**M1**	Using $AC = 2AB$ and solving for a or for substituting $a = 4$ and finding AB and AC
	$a = 4$ m s^{-2}	**A1**	AG, If substituting $a = 4$ must show $AB = 120$ and $AC = 240$ OE
		4	
(ii)	$[v = 14 + 4 \times 8]$	**M1**	Use of $v = u + at$ or any complete method to find v
	Velocity = 46 m s^{-1}	**A1**	
		2	

107. 9709_w17_MS_42 Q: 4

	Answer	Mark	Partial Marks
(i)	$[12t - \frac{1}{2}gt^2 = 0]$ or $[0 = 12 - gT]$ with $t = 2T$ used	**M1**	Using $s = ut + \frac{1}{2}at^2$ or equivalent such as finding time T to highest point and doubling.
	$t = 2.4$ s	**A1**	
		2	
(ii)	Critical point at $t = 1.2$	**B1**	Seen in **4(ii)**
	Critical point at $t = 2$	**B1**	Seen in **4(ii)**
	Both moving in same direction $1 < t < 1.2$	**B1**	
	Both moving in same direction $2 < t < 2.4$	**B1**	
		4	

108. 9709_w17_MS_42 Q: 7

	Answer	Mark	Partial Marks
(i)	$-0.01t(t^2 - 22t + 40) = 0$ $-0.01t(t - 20)(t - 2) = 0$	M1	Attempting to solve $v = 0$ for t for a solvable quadratic using factors or quadratic formula and obtaining two non-zero solutions
	$t = 2$ or $t = 20$	A1	
		2	
(ii)	$a = -0.03t^2 + 0.44t - 0.4$	M1	For differentiation
	a is greatest (maximum) when $0.44 - 0.06t = 0$	M1	For differentiation **or** finding values of $t = t_1$ and $t = t_2$ where $a = 0$ and using $t = ½(t_1 + t_2)$ **or** completing the square **or** other method to find maximum value
	Max acceleration when $t = 7.33$	A1	Allow $t = \frac{22}{3}$
		3	
(iii)	$\int\left(-0.01t^3 + 0.22t^2 - 0.4t\right)\mathrm{d}t$	*M1	For using integration.
	$s(t) = -\frac{0.01}{4}t^4 + \frac{0.22}{3}t^3 - 0.2t^2$	A1	Correct Integration Allow + C included
	$s(20) - s(2)$	DM1	Limits 2 and 20 used correctly Dependent on previous M1 having been scored
	Distance = 107 m	A1	Distance = $\frac{2673}{25}$ = 106.92
		4	

109. 9709_w17_MS_43 Q: 5

	Answer	Mark	Partial Marks
(i)	$v = \int k(3t^2 - 12t + 2)\, dt$ $= k(3t^3/3 - 12t^2/2 + 2t) + C$	*M1	Use of $v = \int a\, dt$
	$v = k\left(t^3 - 6t^2 + 2t\right) + C$	A1	Condone C missing
	$C = 0.4$	B1	
	$0.1 = k(1 - 6 + 2) + 0.4 \quad [-0.3 = -3k]$	DM1	Substitutes $t = 1$, $v = 0.1$
	$k = 0.1$	A1	AG
		5	
(ii)	$[s = \int 0.1(t^3 - 6t^2 + 2t) + 0.4\, dt$ $= 0.1(t^4/4 - 6t^3/3 + 2t^2/2) + 0.4t + C]$	M1	Use of $s = \int v\, dt$
	$s = 0.025t^4 - 0.2t^3 + 0.1t^2 + 0.4t$	A1	$C = 0$ seen or implied
		2	
(iii)	Substitutes $t = 2$ to show $s = 0$	B1	AG
		1	

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110. 9709_w17_MS_43 Q: 6

	Answer	Mark	Partial Marks
(i)	[Area = ½ (10 + 4) × 6 = 42 m] Displacement = 42 m	B1	
		1	
(ii)	$\frac{v}{2} = \frac{6}{4}$ or [gradient =1.5, $v = 6 + 1.5 \times 6$]	M1	Using similar triangles or using acceleration = gradient and $v = u + at$
	$v = 3$ ms^{-1}	A1	
		2	
(iii)	Total distance travelled = 42 + ½ (T – 10) × 3	B1 FT	Area found with FT distance from **(i)** and FT speed from **(ii)**
	[42 + ½ (T – 10) × 3 = 49.5] →T= …	M1	For equation and solving for T
	T = 15 s	A1	
		3	
(iv)	V = 1.75 × 4 = 7 ms^{-1}	B1	
	Q travels [½ (13 + 6) × 7 = 66.5 m] Distance apart = [66.5 + 42 – 7.5]	M1	Finding area for Q and interpreting total distance between particles
	Distance between P and Q = 101 m	A1	
		3	

111. 9709_m16_MS_42 Q: 7

	Answer	Mark		Partial Marks
(i)	$k = 40$	B1	1	
(ii)	Correct for $0 \leqslant t \leqslant 4$	B1√		Quadratic curve with minimum at $t = 1$ approximately, $v = 0$ at $t = 2$ and $v = k$ at $t = 4$. ft on k
	Correct for $4 \leqslant t \leqslant 14$	B1√		Horizontal line at $v = k$. ft on k
	Correct $14 \leqslant t \leqslant 20$	B1√	3	Line with negative gradient from $(14, k)$ to $(20, 28)$. ft on k
(iii)	For $0 \leqslant t \leqslant 4$ $a = 10t - 10$	M1		Attempting to differentiate to find a
	$1 < t \leqslant 4$	A1	2	
(iv)	$\int(5t^2 - 10t)dt =$ $\frac{5}{3}t^3 - 5t^2$	M1		For attempting to integrate the given quadratic expression and attempting to apply limits over the interval $t = 0$ to $t = 4$
	$A = \left[\frac{5}{3}t^3 - 5t^2\right]_0^2 =$ $\left(\frac{5}{3}2^3 - 5 \times 2^2\right)$ $-\left(\frac{5}{3}0^3 - 5 \times 0^2\right)$			Use of limits to obtain A, the integral from $t = 0$ to $t = 2$ and B, the integral from $t = 2$ to $t = 4$ Full evaluation of A not necessary at this stage $\left[A = -\frac{20}{3}\right]$
	$B = \left[\frac{5}{3}t^3 - 5t^2\right]_2^4 =$ $\left(\frac{5}{3}4^3 - 5 \times 4^2\right)$ $-\left(\frac{5}{3}2^3 - 5 \times 2^2\right)$	A1		Full evaluation of B not necessary at this stage $\left[B = \frac{100}{3}\right]$
	$C = (40 \times 10) + 0.5 \times (40 + 28) \times 6$	B1√		For finding the distance travelled in the interval $t = 4$ to $t = 20$ using area properties or integration. ft on k
	$-A + B + C =$ [20/3 + 100/3 + 400 + 204]	M1		For attempting to evaluate the total distance travelled by P in the interval $t = 0$ to $t = 20$. The distance travelled in the first 4 seconds must have been found using integration methods.
	Total distance travelled = 644 m	A1	5	

112. 9709_s16_MS_41 Q: 1

	Answer	Mark		Partial Marks
(i)	Trapezium seen	**B1**		v–t graph with three straight lines, with positive, zero and negative gradients, continuous
	0, 3, 9, 13 shown on the t axis	**B1**		
	$v = 2.7$ soi in either part	**B1**	[3]	
(ii)	$[0.5 \times (6 + 13) \times 2.7]$	**M1**		Using area of trapezium
	Total distance = 25.65 m	**A1**	[2]	Allow Distance = 513/20 m
	Alternative method for 1(ii)			
(ii)	Stage 1 $s_1 = 0.5 \times 0.9 \times 3^2 = 4.05$ Stage 2 $s_2 = 2.7 \times 6 = 16.2$ Stage 3 $s_3 = 0.5 \times (2.7 + 0) \times 4 = 5.4$	**M1**		Complete method to find the total distance travelled by the lift using constant acceleration equations for all three stages
	Total distance = 25.65 m	**A1**	[2]	

113. 9709_s16_MS_41 Q: 6

	Answer	Mark		Partial Marks
(i)	$a = 12t - 30$	**M1**		For differentiating v to find a
	$t < 2.5$	**A1**	[2]	
(ii)	$v = 0$ at $t = 1$ and $t = 4$	**B1**		Using $v = 6(t - 4)(t - 1)$
	$s = \int\left(6t^2 - 30t + 24\right)dt$ $= \frac{6}{3}t^3 - \frac{30}{2}t^2 + 24t$	**M1**		For using integration to find s
	$s = \left[2t^3 - 15t^2 + 24t\right]_1^4$	**M1**		For using limits
	Distance = 27 m	**A1**	[4]	
(iii)	$2t^3 - 15t^2 + 24t = 0$	**M1**		State $s = 0$
	$2t^2 - 15t + 24 = 0$	**M1**		Reduce to a quadratic and attempt to solve
	$t = 2.31$ and $t = 5.19$	**A1**	[3]	

114. 9709_s16_MS_42 Q: 2

	Answer	Mark		Partial Marks
(i)	$4t^2 - 8t + 3 = 0$ $(2t-3)(2t-1)$	**M1**		Set $v = 0$ and attempt to factorise or use the quadratic formula or completing the square.
	$t = 0.5$ and $t = 1.5$	**A1**	2	
(ii)	$s = -\int(4t^2 - 8t + 3)dt$	**M1**		Integrating v to find s. Allow minus sign omitted.
	$-\left[\frac{4}{3}t^3 - 4t^2 + 3t\right]_{0.5}^{1.5}$	**M1**		Attempted integration with limits substituted and then subtracted but not necessarily fully evaluated. [= – (0 – 2/3)] Allow first minus sign omitted
	Distance travelled =2/3 m	**A1**	3	Must justify sign of answer

115. 9709_s16_MS_42 Q: 4

	Answer	Mark		Partial Marks
(i)	½ × 6 × 8.2 + 36 × 8.2 Or½ × 8.2 × (36 + 42)	**M1**		For using distance = total area under graph
	Distance = 319.8 m	**A1**	2	
(ii)	$s = 80.2$	**B1**√		Distance from $t = 42$ to $t = 52$
	$80.2 = \frac{8.2 + V}{2} \times 10$	**M1**		For equating remaining distance to total area under graph between $t = 42$ and $t = 52$
	$V = 7.84$	**A1**	3	**AG**
(iii)		**M1**		Use gradient property for deceleration
	$d = \frac{8.2 - 7.84}{10} = 0.036$	**A1**	2	
	Alternative for 4(iii)			
(iii)	80.2 = 8.2 × 10 + ½ a × 10^2	**M1**		For using $s = ut + ½at^2$ between $t = 42$ and $t = 52$
	$a = –0.036$ ms^{-2} or $d = 0.036$ ms^{-2}	**A1**	2	

116. 9709_s16_MS_43 Q: 2

	Answer	Mark		Partial Marks
(i)	$s_B = ½ \times 1.2 \times 5^2$ Distance travelled is 15 m	B1		
	$v_B = 1.2 \times 5$ Speed is 6 ms^{-1}	B1	2	
(ii)	$[4T = 15 + 6(T – 10)]$ or $[4(T + 5) = 15 + 6(T – 5)]$ or $[4(T + 10) = 15 + 6T]$	M1		For using $s_A = s_B$ after T seconds or after $T + 5$ seconds or after $T + 10$ seconds
	$T = 22.5$or $T = 17.5$or $T = 12.5$	A1		
	Distance OP $= 4 \times 22.5 = 90$ m	B1	3	

117. 9709_s16_MS_43 Q: 7

	Answer	Mark		Partial Marks
(i)	$[6t – 2 < 0 \rightarrow t < .....]$	M1		For solving $a(t) < 0$
	$0 < t < 1/3$	A1	2	
(ii)	$[v = 3t^2 – 2t + c]$	M1		For using $v(t) = \int a(t)dt$
		M1		For using $s(t) = \int v(t)dt$
	$s = t^3 – t^2 + ct + d$	A1		
	$[c + d = 7$ $3c + d = 11 \rightarrow c = ..., d = ...]$	M1		For using t=1, s=7 and t=3, s=29 to form and solve simultaneous equations
	$s = t^3 – t^2 + 2t + 5$	A1	5	
(iii)	$[3t^2 – 2t + 2 = 10]$	M1		For using $v(t) = 10$
		DM1		For solving 3 term quadratic $v(t) = 10$
	$t = 2$	A1	3	

118. 9709_w16_MS_41 Q: 1

	Answer	Mark		Partial Marks
	[$0.4g - T = 0.4a$ $T = 0.6a$ System equation $0.4g = (0.4 + 0.6)a$]	M1		For applying Newton's 2nd law to either particle or to the system
		M1		For applying Newton's 2nd law to the other particle and attempt to solve for a and T
	$a = 4\,\text{m s}^{-2}$	A1		
	$T = 2.4\,\text{N}$	A1	[4]	

119. 9709_w16_MS_41 Q: 3

	Answer	Mark		Partial Marks
(i)	[$0 = 6^2 - 2g \times s$]	M1		For using $v^2 = u^2 + 2as$
	$s = 1.8$	A1		
	Total height = 2.3 m	B1	[3]	
	Alternative for 3(i)			
	[$6^2 = u^2 - 2g \times 0.5$]	M1		For using $v^2 = u^2 + 2as$ to find the initial velocity
	$u^2 = 46$	A1		
	$0^2 = 46 - 2gs \rightarrow s = \text{total height} = 2.3\,\text{m}$	B1	[3]	
(ii)	[$2.3 = 0 + 0.5gt^2$]	M1		For using $s = ut + 0.5gt^2$ to find time to reach the ground
	$t = 0.678$	A1		
	Total time = 2 × 0.678 = 1.36 s	B1	[3]	
	Alternative for 3(ii)			
	[$0 = \sqrt{46} - gt$]	M1		Using $v = u - gt$ to find time taken to the highest point
	$t = \dfrac{\sqrt{46}}{10} = 0.678$	A1		
	Total time = 2 × 0.678 = 1.36 s	B1	[3]	

120. 9709_w16_MS_41 Q: 7

	Answer	Mark		Partial Marks
(i)	$[15 - 6t = 0]$	**M1**		For differentiation
	Max acceleration when $t = 2.5$ s	**A1**		May be stated from an *a-t* diagram
	Max acceleration = $18.75\,\text{m s}^{-2}$	**A1**	[3]	
(ii)	[Speed = $7.5t^2 - t^3$ (+ c)]	**M1**		For using integration to obtain speed
	[Distance = $2.5t^3 - 0.25t^4$ (+ ct + d)]	**M1**		For using integration to obtain distance
	$= 2.5\times125 - 0.25\times625 = 156.25$ m	**A1**	[3]	Allow distance = 625/4
(iii)	$v(5) = 7.5\times25 - 125 = 62.5\,\text{m s}^{-1}$	**B1**		Allow $v(5) = 125/2$
	$\int_5^k -\frac{625}{t^2}\,dt = \left[\frac{625}{t}\right]_5^k$	**M1**		Integral with correct limits
	$= \frac{625}{k} - \frac{625}{5} = \frac{625}{k} - 125$	**A1**		
	$\frac{625}{k} - 125 = v(k) - v(5) = -62.5$	**M1**		Use of $v(5) = 62.5$ and $v(k) = 0$
	$k = 10$	**A1**	[5]	
	Alternative for 7(iii)			
	$v(5) = 7.5\times25 - 125 = 62.5\,\text{m s}^{-1}$	**B1**		
	$v(t) = \int -\frac{625}{t^2}\,dt = \frac{625}{t} + c$	**M1**		Using indefinite integration
	$[c = -62.5]$ $v(t) = \frac{625}{t} - 62.5$	**A1**		For using $v(5) = 62.5$ to find c and setting $v(k) = 0$
	$v(k) = \frac{625}{k} - 62.5 = 0$	**M1**		
	$k = 10$	**A1**	[5]	

121. 9709_w16_MS_42 Q: 2

	Answer	Mark		Partial Marks
(i)	$[v = 4t - 40t^{0.5}]$	**M1***		For differentiating s to find v
	$[a = 4 - 20t^{-0.5}]$	**M1***		For differentiating v to find a
	$[4 - 20t^{-0.5} = 0]$	**DM1**		For setting $a = 0$ and attempt to solve to find t
	$t = 25$ s	**A1**	[4]	
(ii)	Substitute their t into s **or** v	**M1**		
	Displacement= –2083.3 m(= –2080 3sf) **and** Velocity = -100ms^{-1}	**A1**	[2]	or Displacement = – 6250 / 3

122. 9709_w16_MS_42 Q: 7

	Answer	Mark		Partial Marks
(i)	$v = 3 \times 10 = 30\text{ms}^{-1}$	**B1**		Velocity after 10 seconds
	$[s = ½ (30 + 40) \times 30]$ or equivalent complete method	**M1**		For determining distance travelled in first 40 seconds
	Total distance = 1050 m	**A1**	[3]	
(ii)	[Distance = 450 m Time taken = 450 / 15 = 30 s]	**M1**		For finding distance covered in deceleration stage and time taken for this stage
	Total time of motion for car = 70 s	**A1**		May be implied by time for motorcycle = 50 s
	[Motorcycle takes 50 s to travel 1500 m $1500 = ½ (30 + 50) \times V$ or $1500 = 30V + 0.5 \times 20V$]	**M1**		For setting up an equation for distance travelled by M/C (v–t graph or other) involving V or a and up to one other variable.
	$V = 37.5\text{ms}^{-1}$	**A1**		
	[20 s is split between 5 s accelerating and 15 s decelerating]	**M1**		For finding time taken to accelerate to speed V
	$a = 37.5 / 5 = 7.5\text{ms}^{-2}$	**A1**	[6]	
(iii)	Displacement-time graph	**B1**		Two of the three graph stages correct with correct curvature
		B1		All three stages of the graph correct with correct curvature
		B1	[3]	Correct graph, fully labelled t=10,40,70s = 150,1050, 1500

123. 9709_w16_MS_43 Q: 4

	Answer	Mark		Partial Marks
(i)	$s_A = ½g \times 2.5^2$ (= 31.25)	B1		
	[$s_B = 20 \times 1.5 - ½g \times 1.5^2$] (= 18.75)	M1		For using $s = ut + ½ at^2$
	$½g \times 2.5^2 + 20 \times 1.5 - ½g \times 1.5^2$ Height is 50 m AG	A1	[3]	
(ii)	$50 = 0.5gt_A^2$ ($t_A = 3.16$)	B1		For using $s = ½ at^2$
	$t_B = \sqrt{10} - 1 = 2.16$	B1		
	To top, $0^2 = 20^2 - 2gs_B$ $\rightarrow s_B = 20$	B1		
	To top, [$0 = 20 - gt_B$] $\rightarrow t_B = 2$ Downwards, [$s_B = ½g(0.16)^2$] (= 0.13)	M1		For using $v = u + at$ to find time to top for B **and** $s = ½at^2$ to find downwards distance for B
	Total distance is 20.1 m	A1	[5]	

124. 9709_w16_MS_43 Q: 5

	Answer	Mark		Partial Marks
(i)	$6t - 0.3t^2 = 0 \rightarrow t = 20$ (or 0)	B1		
	[$s = 6t^2/2 - 0.3t^3/3$ (+C)]	M1		For integrating $v(t)$ to obtain $s(t)$
	[$s = 6(20)^2/2 - 0.3(20)^3/3$]	DM1		For evaluating $s(t)$ when v=0
	Distance OX is 400 m	A1	[4]	
(ii)	[$v = kt - 6t^2$ (+C)]	M1*		For integrating $a(t)$ to obtain $v(t)$
	[$s = kt^2/2 - 6t^3/3$]	M1*		For integrating $v(t)$ to obtain $s(t)$ and for using $s(0) = 0$
	[$400 = 0.5k \times 10^2 - 2 \times 10^3$]	DM1		For using $t = 10$ and $s = 400$ to form equation in k
	$k = 48$	A1	[4]	

125. 9709_s15_MS_41 Q: 6

	Answer	Mark		Partial Marks
(i)		M1		For integrating $a(t)$ to find $v(t)$
	$v(t) = 0.05t - 0.0001t^2 \quad (+ 0)$	A1		
	$v(200) = 10 - 4 = 6 \text{ ms}^{-1}$	A1		
	$v(500) = 25 - 25 = 0$	A1	4	
(ii)		M1		For integrating $v(t)$ between limits 0 to 500 to obtain the distance A travels
	$\int_0^{500} \left(0.05t - 0.0001t^2\right) dt$ $\left[\frac{0.05t^2}{2} - \frac{0.0001t^3}{3}\right]_0^{500}$	A1		
	Distance = $0.025 \times 500^2 - 0.0001 \times 500^3 \div 3 = 2083$ m	A1		Accept 2080
		M1		For using area property of graph or $s = \frac{1}{2}(u + v)t$ or $s = ut + \frac{1}{2}at^2$ to find distance travelled by B
	Distance = $\frac{1}{2} \times 6 \times 500 = 1500$ m **or** distance = $\frac{1}{2}(0+6)\times 200 + \frac{1}{2}(6+0)\times 300$ **or** distance = $\left(0 + \frac{1}{2}0.03 \times 200^2\right) + \left(6 \times 300 + \frac{1}{2}(-0.02)300^2\right)$	A1		
	Distance between A and B is $2083 - 1500 = 583$ m	B1√	6	Can only be scored if distance travelled by A has been found using integration

126. 9709_s15_MS_42 Q: 4

	Answer	Mark		Partial Marks
(i)		M1		For integrating to obtain $v(t)$.
	$v(t) = 0.025t^3 - 0.75t^2 + 5t \quad (+0)$	A1		
		M1		For integrating to obtain $s(t)$.
	$s(t) = 0.00625t^4 - 0.25t^3 + 2.5t^2 \quad (+0)$	A1	4	
(ii)		M1		For setting $s = 0$ (t not zero) in their attempt at s which was obtained using integration only.
	$[t^4 - 40t^3 + 400t^2 = 0 \rightarrow t^2(t - 20)^2 = 0]$	M1		For attempting to solve a quartic equation for $s = 0$ where s was obtained using integration only.
	Time taken is 20 s	A1	3	$t = 20$ only

127. 9709_s15_MS_42 Q: 5

	Answer	Mark		Partial Marks
(i)		M1		For using $v = u - gt$ to find the time taken by Q. Must be for a complete method for the total time taken to return to point A
	$-20 = 20 - 10t$ ➔ time taken is 4s or $0 = 20 - 10t$ ➔ time taken is $2 \times 2\text{s} = 4\text{s}$	A1		
	$[30 = 0 + 4a]$	M1		For using $v = u + at$ to find the acceleration of P
	Acceleration of P is 7.5 ms^{-2}	A1√	4	ft on an incorrect positive value of the time taken
(ii)		M1		For using $v^2 = u^2 + 2as$ **or** $s = \frac{(u+v)}{2}t$ **or** $s = ut + \frac{1}{2}at^2$ **or** $s = vt - \frac{1}{2}at^2$ to find the distance OA
	Either $30^2 = 2 \times 7.5 \times OA$ **or** $OA = \frac{(0+30)}{2} \times 4$ **or** $OA = \frac{1}{2} \times 7.5 \times 4^2$ **or** $OA = 30 \times 4 - \frac{1}{2} \times 7.5 \times 4^2$ ➔ Distance OA is 60 m	A1	2	

128. 9709_s15_MS_43 Q: 7

	Answer	Mark		Partial Marks
(i)	[$0.0001t(t-50)(t-100)=0$ or $v(0)=0$, $v(50)=0$, $v(100)=0$]	M1		Either factorise $v(t)$ and solve $v(t)=0$ or evaluate $v(0)$, $v(50)$ and $v(100)$
	$v(t)=0$ when $t=0$, 50 & 100	A1	2	
(ii)	[$0.0003t^2-0.03t+0.5=0$]	M1		For using $a(t)=\dfrac{dv}{dt}$
	$t^2-100t+1667=0 \rightarrow$ $t=\left[\frac{1}{2}\left\{100\pm\sqrt{(100^2-4\times1667)}\right\}\right]$	dM1		For solving $a(t)=0$
	$a=0$ when $t=21.1$ and when $t=78.9$	A1		
	$v(21.1)=4.81$	B1		
	$v(78.9)=-4.81$	B1		
	Convex curve from (0,0) to (50,0) with $v>0$ and has a maximum point.	B1		
	The curve for (50, 0) to (100, 0) is exactly the same as the first curve positioned by rotating the first curve through 180° about the point (50, 0).	B1	7	
(iii)		M1		For integrating $v(t)$ to obtain $s(t)$
	$s(t)=0.000025t^4-0.005t^3+0.25t^2\ (+c)$	A1		
	[$156.25-625+625$]	M1		For using lower and upper limits of 0 and 50 respectively.
	Greatest distance is 156 m	A1	4	

129. 9709_w15_MS_41 Q: 6

	Answer	Mark		Partial Marks
(i)	$s = 0.3t^2 - 0.01t^3$	**M1**		For integration
	$s(5) = 0.3 \times 5^2 - 0.01 \times 5^3 = 6.25$	**A1**		
	$a = 0.6 - 0.06t$	**M1**		For differentiation
	$a(5) = 0.6 - 0.0 \times 5 = 0.3$ ms^{-2}	**A1**	4	
(ii)	Maximum velocity is when $0.6 - 0.06t = 0$	**M1**		For setting $a = 0$
	$[t = 10]$	**M1**		For solving $a = 0$
	Max velocity = 3 ms^{-1}	**A1**		
	$0.6t - 0.03t^2 = 1.5$			Setting velocity = half its maximum and attempting to solve a three term quadratic
	$[t^2 - 20t + 50 = 0]$	**M1**		
	Times are 2.93 s	**A1**		
	and 17.07 s	**A1**	6	

130. 9709_w15_MS_41 Q: 7

	Answer	Mark		Partial Marks
(i)	$36 = 0 + 0.5 \times 0.5t^2$			
	$t = 12$	**B1**		
	$v^2 = 0 + 2 \times 0.5 \times 36$			
	$v = 6$	**B1**		
	$s = 6 \times 25$			
	remaining distance $= 210 - 36 - 150 = 24$	**B1**		
	$24 = (6 + 0)/2 \times t$	**M1**		Using $s = (u + v)t/2$
	$t = 8$			
	Total Time = $12 + 25 + 8 = 45$ s	**A1**	5	
(ii)	Distance travelled by cyclist $= 36 + 6(t - 12)$	**M1**		For attempting distance travelled by cyclist for $t > 12$
	Distance travelled by car $= 0.5 \times 4 \times (t - 24)^2$	**M1**		For attempting distance travelled by car
	$2t^2 - 96t + 1152 = 36 + 6t - 72$ $[t^2 - 51t + 594 = 0]$	**M1**		Equating expressions and attempting to solve a three term quadratic equation
	$t = 33$ or $t = 18$	**A1**		
	Time = 33 s	**B1**	5	Choosing the correct solution

131. 9709_w15_MS_42 Q: 2

	Answer	Mark		Partial Marks
(i)	$[V^2 = (V - 10)^2 + 2g \times 35]$	M1		For using $v^2 = u^2 + 2gs$ to obtain an equation in V only **or** to obtain two equations in V and H and attempting to eliminate H
	$20V = 100 + 70g$	A1		
	$V = 40$	A1	3	
	Alternative for 2(i)			
(i)		M1		A complete method to find V by considering the final 35 m using $v = u + at$ and either $s = ut + \frac{1}{2}at^2$ or $s = (u + v)/2 \times t$
	$V = V - 10 + 10t \rightarrow t = 1$ and $35 = (V - 10) \times 1 + \frac{1}{2} \times 10 \times 1^2$ or $35 = (V - 10 + V)/2 \times 1$	A1		
	$V = 40$	A1	3	
(ii)	$[40^2 = 0^2 + 20H]$	M1		For using $v^2 = u^2 + 2gs$
	$H = 80$	A1	2	

132. 9709_w15_MS_42 Q: 3

	Answer	Mark		Partial Marks
(i)	$[a(t) = 0.00012t^2 - 0.012t + 0.288]$	M1*		For attempting to differentiate $v(t)$
	$[a(t) = 0.00012(t^2 - 100t + 2400)$ $= 0.00012(t - 40)(t - 60) = 0]$	dM1*		For setting $a(t) = 0$ and attempting to solve a three term quadratic
	$a(t) = 0$ when $t = 40$ and $t = 60$	A1	3	
(ii)	$[0.00001t^4 - 0.002t^3 + 0.144t^2]$	M1†		For attempting to integrate $v(t)$
	$[0.00001(100)^4 - 0.002(100)^3 + 0.144(100)^2]$	dM1†		Integration attempted using correct limits $t = 0$ to $t = 100$
	Displacement is 440 m	A1	3	

133. 9709_w15_MS_43 Q: 6

		Answer	Mark		Partial Marks
(i)		Time taken $= \dfrac{0.08}{0.0002} = 400$ s	B1		
		$v = \dfrac{dx}{dt} = 0.16t - 0.0006t^2$	B1		
		[speed $= -0.16 \times 400 + 0.0006 \times 400^2$]	M1		For evaluating $\pm v(400)$
		Speed at O is 32 ms^{-1}	A1	4	
(ii)	(a)	Time to furthest point is 0.16 / 0.0006 s	B1√		√ $v = 0.16t - kt^2$ or $v = kt - 0.0006t^2$ from part (i)
		[$0.08(800/3)^2 - 0.0002(800/3)^3$] (×2)	M1*		For evaluating $x(t_{\text{furthest point}})$ (×2)
		Distance moved is 3790 m	A1	3	
	(b)	[speed = 3790 / 400 ms^{-1}]	dM1*		For using 'average speed = total distance moved / time taken'
		Average speed is 9.48 ms^{-1}	A1	2	

134. 9709_s20_MS_43 Q: 1

	Use of conservation of momentum	M1
	$m \times 2 + 0 = m \times (-0.5) + 0.2 \times 1$	A1
	$m = 0.08$	A1
		3

135. 9709_W20_MS_42 Q: 1

	Answer	Mark	Partial Marks
(a)	Momentum = $0.2 \times 2 = 0.4$ kg ms^{-1}	B1	
		1	
(b)	$0.4 = 0.2 \times 0.3 + 0.5v$	M1	Apply conservation of momentum, 3 terms
	$v = 0.68$ ms^{-1}	A1 FT	FT on answer in **1(a)**
		2	

136. 9709_s20_MS_41 Q: 7

(a)	$0.3g\sin 30 = 0.3a$ $(a = 5)$ (**M1** for applying Newton's second law parallel to the plane)	**M1**
	$v^2 = 0 + 2 \times 2.5 \times a$	**M1**
	$v = 5$	**A1**
	$0.3 \times 5 + 0 = 0.3 \times 2 + 0.2\,w$	**M1**
	Velocity of $Q = 4.5\ \text{ms}^{-1}$	**A1**
		5
(b)	$0.3 \times z + 0 = 0.5 \times 1.2$	**M1**
	Velocity of P before collision $z = 2$	**A1**
	Friction force on P after reaches horizontal plane $F = \mu \times 0.3\,g$	**B1**
	$\mu \times 0.3g \times 1.5 = \frac{1}{2} \times 0.3 \times 5^2 - \frac{1}{2} \times 0.3 \times 2^2$	**M1**
	Coefficient $\mu = 0.7$	**A1**
	Alternative method for question 7(b)	
	$0.3 \times z + 0 = 0.5 \times 1.2$	**M1**
	Velocity of P before collision $z = 2$	**A1**
	Friction force on P after reaches horizontal plane $F = \mu \times 0.3\,g$	**B1**
	$a = (5^2 - 2^2)/(2 \times 1.5) = 7$, $F = 0.3 \times 7$	**M1**
	Coefficient $\mu = 0.7$	**A1**
		5

137. 9709_s20_MS_43 Q: 2

(a)	$F - 900 = 4000 \times 0.5$ (**M1** for use of Newton's second law, 3 terms)	**M1**
	$F = 2900$ N	**A1**
(b)	900×25 (**M1** for use of $P = Fv$ with F = resistance only)	**M1**
	22 500 W or 22.5 kW	**A1**

138. 9709_s20_MS_43 Q: 7

(a)	$T - 2mg = 0$	**B1**
	$3mg\sin\theta - T = 0$ (**M1** for resolving forces parallel to the plane and solving for θ)	**M1**
	$\theta = 41.8$ (41.810...)	**A1**
		3
(b)	$R = 3mg\cos 30$	**B1**
	Use of $F = \mu R$	**M1**
	$2mg - T = 0.1 \times 2m$ OR $T - 3mg\sin 30 - \mu \times 3mg\cos 30 = 0.1 \times 3m$	**M1**
	$2mg - 0.2m - 3mg\sin 30 - \mu \times 3mg\cos 30 = 0.1 \times 3m$	**M1**
	$\mu = \frac{\sqrt{3}}{10}$	**A1**
		5
(c)	$v^2 = 0 + 2 \times 0.1 \times 0.8 \quad (v = 0.4)$	**M1**
	$-3mg\sin 30 - \mu \times 3mg\cos 30 = 3ma \ (a = -6.5)$	**M1**
	$0 = -0.4 - 6.5t$	**M1**
	$t = 0.4/6.5 = 0.0615$ s	**A1**
		4

139. 9709_W20_MS_41 Q: 2

	Answer	Mark	Partial Marks
(a)	$P = 350 \times 20$	**M1**	Using $P = Fv$
	$P = 7$ kW	**A1**	
		2	
(b)	$15\,000 = \text{DF} \times 20 \quad [\text{DF} = 750]$	**B1**	Using $P = Fv$
	$\text{DF} - 350 = 1400a$	**M1**	Use Newton's 2nd law, 3 terms
	$a = \frac{2}{7}\ \text{ms}^{-2}$	**A1**	$a = 0.286$
		3	

140. 9709_W20_MS_41 Q: 5

	Answer	Mark	Partial Marks
(a)	$0.8g - T = 0.8a$, $T - 0.2g = 0.2a$, For system: $0.8g - 0.2g = (0.8 + 0.2)a$	M1	Apply Newton's 2nd law to either particle or to the system
		A1	Any 2 correct equations
	Attempt to solve for either a or T	M1	
	$a = 6\text{ ms}^{-2}$ and $T = 3.2\text{ N}$	A1	AG. Both correct
		4	
(b)	$v^2 = 2 \times 6 \times 0.5$	M1	Attempt to find v or v^2 as 0.8 kg particle reaches the ground using a from **5(a)**
	$0 = 6 - 20s$	M1	Attempt to find the extra height reached by 0.2 kg particle using v^2 from previous M1 mark
	Greatest height = 0.5 + 0.5 + 0.3 = 1.3 m	A1	
		3	

141. 9709_W20_MS_42 Q: 6

	Answer	Mark	Partial Marks
(a)	$R = 5g\cos 30$ $[= 25\sqrt{3}]$	B1	
	$40 - 5g\sin 30 - F > 0$	M1	State that the net force up the plane is positive, 3 terms
	$F = \mu \times 5g\cos 30$	M1	For using $F = \mu R$ with R as a component of $5g$ to obtain an equality/inequality in μ only with 3 terms
	$\mu < \frac{1}{5}\sqrt{3}$	A1	AG
	Alternative scheme for question 6(a)		
	$R = 5g\cos 30$ $[= 25\sqrt{3}]$	B1	
	$40 - 5g\sin 30 - F = 5a$	M1	Acceleration $a > 0$
	$F = \mu \times 5g\cos 30$ $[40 - 5g\sin 30 - \mu \times 5g\cos 30 = 5a]$	M1	For using $F = \mu R$ with R as a component of $5g$ to obtain an equality in μ and a
	$\mu < \frac{1}{5}\sqrt{3}$	A1	AG. From $\mu = \frac{1}{5}\sqrt{3} = \frac{a}{g}\cos 30$ with $a > 0$
		4	
(b)	Attempt to resolve forces parallel to or perpendicular to the inclined plane, 3 relevant terms in either direction	M1	
	$R = 5g\cos 30 + 40\sin 30$ $[= 20 + 25\sqrt{3} = 63.3]$	A1	
	$F = 40\cos 30 - 5g\sin 30$ $[= 20\sqrt{3} - 25 = 9.64]$	A1	
	$\mu \geqslant 0.152$	B1	AG. Using $F \leqslant \mu R$
	Alternative method for question 6(b)		
	Attempt to resolve forces horizontally or vertically with 3 relevant terms in either direction	M1	
	$40 = R\sin 30 + F\cos 30$ $[40 = ½R + \sqrt{3}/2F]$	A1	
	$5g = R\cos 30 - F\sin 30$ $[5g = \sqrt{3}/2R - ½F]$	A1	
	$\mu \geqslant 0.152$	B1	AG. Solve for R and F and use $F \leqslant \mu R$

142. 9709_W20_MS_43 Q: 7

	Answer	Mark	Partial Marks
(a)	[$T = 2g \sin 10$] or [$3g \sin 20 = F + T$]	**M1**	Resolve forces parallel to plane P for particle A or parallel to plane Q for Particle B
	$T = 2g \sin 10$ **and** $3g \sin 20 = F + T$	**A1**	
	$R = 30 \cos 20$ (= 28.19...)	**B1**	Resolving forces perpendicular to plane Q for particle B
	$\mu = \dfrac{3g\sin 20 - 2g\sin 10}{30\cos 20}$	**M1**	Using $\mu = F/R$
	$\mu = 0.241$ (=0.2407…)	**A1**	
		5	
(b)	$3g \sin 20 - T = 3a$ or $T - 2g \sin 10 = 2a$ or System: $3g \sin 20 - 2g \sin 10 = 5a$	**M1**	For applying Newton's second law to either A or to B or to the system
	$a = \dfrac{(3g\sin 20 - 2g\sin 10)}{5}$	**M1**	For applying Newton's second law to the second particle and/or solving for a
	$a = 1.3575…$	**A1**	
	$h_1 = x \sin 20$ $h_2 = x \sin 10$ $x \sin 20 + x \sin 10 = 1$	**B1**	Using expressions for height change of each particle after each moves a distance x along the plane, to obtain equation in x
	$\dfrac{1}{\sin 10 + \sin 20} = 0 + \dfrac{1}{2} \times 1.3575 \times t^2$	**M1**	For using $s = ut + ½at^2$ for either particle with $s = x$, $u = 0$ and using *their* a (= 1.3575)
	$t = 1.69$	**A1**	
		6	

143. 9709_s19_MS_42 Q: 4

	Answer	Mark	Partial Marks
	[$1200 - 350 - 1250 \times 10 \times 0.05 = 1250a$]	**M1**	Apply Newton's second law for motion up the hill
	[$a = 225/1250 = 0.18$]	**A1**	Correct Newton's law for motion up the hill
	[$1200 - 350 + 1250 \times 10 \times 0.05 = 1250a$]	**M1**	Apply Newton's second law for motion down the hill
	[$a = 1475/1250 = 1.18$]	**A1**	Correct Newton's law for motion down the hill
	Up the hill: $v^2 = 0 + 2 \times 0.18 \times 100$ Down the hill: $v^2 = 0 + 2 \times 1.18 \times 100$	**M1**	Use their a in the constant acceleration equations either to find v going up or going down the hill
	Up the hill: $v = 6\ \text{ms}^{-1}$	**A1**	
	Down the hill: $v = 15.4\ \text{ms}^{-1}$	**A1**	Allow $v = 2\sqrt{59}$
	Alternative method for question 4		
	[$1200 \times 100 = 350 \times 100 + 1250g \times 100 \times 0.05 + ½ \times 1250 \times v^2$]	**M1**	Attempt the work-energy equation for motion up the hill
		A1	Correct work-energy equation for motion up the hill
	[$1200 \times 100 + 1250g \times 100 \times 0.05 = 350 \times 100 + ½ \times 1250 \times v^2$]	**M1**	Attempt work-energy equation for motion down the hill
		A1	Correct work-energy equation for motion down the hill
		M1	Attempt to solve either energy equation to find either v going up the hill or v going down the hill
	Up the hill: $v = 6\ \text{ms}^{-1}$	**A1**	
	Down the hill: $v = 15.4\ \text{ms}^{-1}$	**A1**	Allow $v = 2\sqrt{59}$
		7	

144. 9709_s19_MS_42 Q: 5

	Answer	Mark	Partial Marks
(i)	A: $4 - T = 0.4a$ B: $T - 2 = 0.2a$ System: $4 - 2 = (0.4 + 0.2)a$	**M1**	Apply Newton' second law to particle A (3 terms) or to particle B (3 terms) or to the system (4 terms implied)
		A1	Two correct equations
		M1	Either solve the system equation for a or solve two simultaneous equations for a or T or verify the given value of a by finding the same T value in both equations
	$a = \frac{10}{3}$, $T = \frac{8}{3}$	**A1**	Both correct **AG**
		4	
(ii)		**M1**	Apply $v^2 = u^2 + 2as$ to particle A or particle B with $a = 10/3$
	$v^2 = 0 + 2 \times 10/3 \times 0.5$	**A1**	[$v = 1.83$ but not needed specifically]
	$0 = 10/3 - 2 \times 10 \times s$ [$s = \frac{1}{6}$]	**M1**	Apply $v^2 = u^2 + 2as$ to particle B to find s, the distance travelled by B after A has hit the ground
	Maximum height $= \frac{7}{6} = 1.17$ m	**A1**	Maximum height $= 1/2 + 1/2 + 1/6 = 7/6 = 1.17$
		4	

145. 9709_s19_MS_43 Q: 4

	Answer	Mark	Partial Marks
(i)	Particle A: [$1.3g - T = 1.3a$] or Particle B: [$T - 0.7g = 0.7a$]	M1	Use of Newton's Second law for A or B or use of $a = (m_A - m_B)g/(m_A + m_B)$
	$1.3g - T = 1.3a$ and $T - 0.7g = 0.7a$ OR $a = \frac{(1.3-0.7)g}{(1.3+0.7)}$ and $1.3g - T = 1.3a$ or $T - 0.7g = 0.7a$	A1	Two correct equations
	[$6 = 2a$, a=3] or [$\frac{1.3g-T}{1.3} = \frac{T-0.7g}{0.7}$, $T = 9.1$]	M1	Solves for a or for T
	$a = 3\text{ ms}^{-2}$ and $T = 9.1$ N	A1	($a = 3$)
		4	
(ii)	Distance while connected = 0.375 m	B1	
	[$v^2 = 0^2 + 2 \times 3 \times 0.375 \rightarrow v = ...$]	M1	Use of *suvat* to find v at 'break' ($v^2 = 2as$)
	$v = 1.5\text{ ms}^{-1}$	A1	Correct value or expression for v
	[A: $1.375 = 1.5t + ½gt^2 \rightarrow t = 0.395...$]	M1	Finds one time 'from break to floor'
	[B: $1.375 = -1.5t + ½gt^2$ or $-1.375 = 1.5t - ½gt^2 \rightarrow t = 0.695...$]	M1	Finds second time 'from break to floor'
	Difference in times = 0.3 s	A1	
	Alternative Method 1 for 4(ii) (last 3 marks)		
	[$u_B = 1.5$, $v_B = 0$, $a = -g$, $0 = 1.5 - gt \rightarrow t = 0.15$]	M1	Finds t_B from 'break' to maximum height
	Difference in times = 2 × 0.15	M1	
	Difference in times = 0.3 s	A1	
(ii)	**Alternative Method 2 for 4(ii) (last 3 marks)**		
	[A: $0.375 = ½ \times 3t^2 \rightarrow t = 0.5$ $1.375 = 1.5t + ½gt^2 \rightarrow t = 0.395...$ t_A total = 0.5 + 0.395... = 0.895... s]	M1	Use of *suvat* to find total time for A
	[B: $0.375 = ½ \times 3t^2 \rightarrow t = 0.5$; $0 = 1.5 - gt \rightarrow t = 0.15$, $s = 1.5t - 1/2gt^2 = 0.1125$ $1.4875 = ½ \times gt^2 \rightarrow t = 0.545...$ t_B total = 1.195 s]	M1	Use of *suvat* to find total time for B
	Difference in times = 0.3 s	A1	
		6	

146. 9709_w19_MS_41 Q: 3

	Answer	Mark	Partial Marks
(i)	$R = 3g\cos 60$	B1	
	Use $F = \mu R$	M1	
	[$3g\sin 60 - \mu 3g\cos 60 - 15 = 0$]	M1	Resolve forces parallel to the plane, 3 terms
		A1	Correct equation
	$\mu = 0.732$	A1	Allow $\mu = \sqrt{3} - 1$
		5	
(ii)	[Maximum force = $3g\sin 60 + F$ $= 3\sin 60 + \mu 3g\cos 60$]	M1	
	$X = 37(.0)$	A1	Allow $X = 15\left(2\sqrt{3} - 1\right)$
		2	

147. 9709_w19_MS_41 Q: 4

	Answer	Mark	Partial Marks
(i)	Apply Newton's second law to either or to the system	M1	
	Block A: $T - 4g \times \frac{7}{25} = 4a$ Block B: $36 - T - 5g \times \frac{7}{25} = 5a$ System: $36 - 5g \times \frac{7}{25} - 4g \times \frac{7}{25} = 9a$	A1	Any two correct. Allow α = 16.3 used.
	Either solving the system for a or solving a pair of simultaneous equations for either a or T	M1	
	$a = 1.2 \text{ ms}^{-2}$	A1	
	$T = 16$ N	A1	
		5	
(ii)	$\left[0.65 = 1 \times t + \frac{1}{2} \times 1.2t^2\right]$	M1	Use constant acceleration equation(s) with $u = 1$ and solve a 3 term quadratic equation to find t
	$t = 0.5$ s	A1	
	Alternative method for question 4(ii)		
	$v^2 = 1^2 + 2 \times 1.2 \times 0.65$ $[v = 1.6]$ and $0.65 = \frac{1}{2}(1+v) \times t$	M1	Use relevant constant acceleration equations with $u = 1$ in a complete method to find t
	$t = 0.5$ s	A1	
		2	

148. 9709_w19_MS_41 Q: 5

	Answer	Mark	Partial Marks
(i)	Resolve forces either horizontally or vertically	**M1**	
	$7.5\cos60 + 4.5\cos20 = F\cos\theta$ [= 7.97861]	**A1**	
	$7.5\sin60 - 4.5\sin20 = F\sin\theta$ [= 4.95609]	**A1**	
	$F = \sqrt{(7.98^2 + 4.96^2)}$	**M1**	Use Pythagoras or use the value found for θ to find F
	$\theta = \tan^{-1}(\frac{4.96}{7.98})$	**M1**	Use trigonometry or the value found for F to find θ
	$F = 9.39$ and $\theta = 31.8$	**A1**	
	Alternative method for question 5(i)		
	$\frac{F}{\sin80} = \frac{4.5}{\sin(120+\theta)} = \frac{7.5}{\sin(160-\theta)}$	**M1**	Attempt to use Lami
		A1	One correct pair of terms
		A1	A second correct pair of terms
	$[4.5\sin(160 - \theta) = 7.5\sin(120 + \theta)]$	**M1**	Attempt to solve for θ
	Use the θ value found by valid trigonometry to find F	**M1**	
	$F = 9.39$ and $\theta = 31.8$	**A1**	
(i)	**Alternative method for question 5(i)**		
	Forces 4.5, 7.5, F opposite angles $60 - \theta$, $\theta + 20$, 100	**M1**	Illustrate a triangle of forces
	$[F^2 = 4.5^2 + 7.5^2 - 2 \times 4.5 \times 7.5 \times \cos100]$	**M1**	For application of cosine rule to find F
		A1	Correct equation
	$\left[\frac{9.39}{\sin100} = \frac{4.5}{\sin(60-\theta)} = \frac{7.5}{\sin(\theta+20)}\right]$	**M1**	One application of the sine rule to find θ
		A1	Correct equation
	$F = 9.39$ and $\theta = 31.8$	**A1**	
		6	
(ii)	$9.5\cos30 - 7.5\cos60 - 4.5\cos20 = m \times 1.5$	**M1**	Apply Newton's second law to the ring along AB (4 terms)
	$m = 0.166$ kg	**A1**	
		2	

149. 9709_w19_MS_41 Q: 6

	Answer	Mark	Partial Marks
(i)	$0.4g \times 1.8 = \frac{1}{2} \times 0.4 \times v^2$	M1	KE gain = PE lost
	$v = 6 \text{ ms}^{-1}$	A1	
	Alternative method for question 6(i)		
	$v^2 = 0^2 + 2 \times g \times 1.8$	M1	Use constant acceleration equation(s) with $a = g$ to find v
	$v = 6 \text{ ms}^{-1}$	A1	
		2	
(ii)	$0.4g - 5.6 = 0.4a$	M1	Use Newton's second law for the particle in the vertical (3 terms)
	$a = -4 \text{ ms}^{-2}$	A1	
	$0 = 6 - 4t$	M1	Use of constant acceleration equation(s) such as $v = u + at$ to find t
	$t = 1.5$ s	A1	
		4	
(iii)	Straight line starting at (0,0) with positive gradient	B1	
	Second straight line starting at end of the first line with negative gradient and ending with $v = 0$	B1	
	All correct, start at (0, 0) with max velocity $v = 6$ at $t = 0.6$ i.e. (0.6, 6) and finishing at (2.1, 0)	B1FT	FT on *their* v from **(i)** and/or *their* t from **(ii)**
		3	

150. 9709_w19_MS_42 Q: 6

	Answer	Mark	Partial Marks
(i)	$4.5 = 0 + \frac{1}{2} \times a \times 5^2$	M1	For use of $s = ut + \frac{1}{2}at^2$ to find a
	$a = 0.36$	A1	
	$6 \times \frac{24}{25} - F = 3 \times 0.36$	M1	Resolving horizontally. Allow use of $\theta = 16.3$
	$F = 4.68$ N	A1	
		4	
(ii)	$R = 3g - 6\sin 16.3 = 3g - 6 \times \frac{7}{25}$ $[= 28.32]$	B1	
	$4.68 = \mu \times 28.32$	M1	Use of $F = \mu R$
	$\mu = 0.165$ $(0.165254\ldots)$	A1	AG. Allow $\mu = \frac{39}{236}$
		3	
(iii)	$v = 5 \times 0.36$ $[= 1.8]$ or $v = \sqrt{(2 \times 0.36 \times 4.5)}$ $[= 1.8]$	B1FT	For velocity at $t = 5$ ft on *their* a from **6(i)**
	$3a = -0.165 \times 3g$	M1	Using Newton's second law with new frictional force
	$0 = 1.8 - 0.165gt$ $(t = 1.09)$	M1	Using constant acceleration equations which would lead to a positive value of t
	Total time $= 5 + 1.09 = 6.09$ s	A1	
		4	

151. 9709_w19_MS_42 Q: 7

	Answer	Mark	Partial Marks
(i)		M1	Use of Newton's second law for P or Q or the system
	For P: $T-0.3g\times\frac{3}{5}=T-0.3g\sin 36.9=0.3a$ For Q: $0.2g-T=0.2a$ System: $0.2g-0.3g\times\frac{3}{5}=(0.2+0.3)a$ or $0.2g-0.3g\sin 36.9=(0.2+0.3)a$	A1	Two correct equations Allow use of $\theta=36.9$
	$[0.2g-0.18g=0.5a]$	M1	For solving either the system for a or for solving a pair of simultaneous equations for a or T
	$a=0.4\text{ ms}^{-2}$	A1	
	$T=1.92$ N	A1	
		5	
(ii)	$0.8=0+\frac{1}{2}\times 0.4\times t^2$ a	M1	For use of the constant acceleration equations with *their* a from **7(i)** and $a\neq\pm g$ for a complete method to find t
	$t=2$ s	A1	
		2	
(iii)	Speed when Q hits the floor $=2\times 0.4\ (=0.8)$ or $v=\sqrt{(2\times 0.4\times 0.8)}\,[=0.8]$	B1FT	Using $v=u+at$ with $u=0$ Allow FT for *their* unsimplified $v=at$ or $v^2=2as$ with a from **(i)**, t from **(ii)** and $s=0.8$
	$-0.3g\times\frac{3}{5}=-0.3g\sin 36.9=0.3a\ \ [a=-6]$	M1	Using Newton's second law for P to find $a\neq\pm g$
	$0=0.8t+\frac{1}{2}\times(-6)t^2\ (t=0.2666...)$ or $0=0.8-6T$ $(T=0.13333=\frac{2}{15}$ and $t=2T=0.26666=\frac{4}{15})$	M1	Use of the constant acceleration equation(s) to find the time taken for P to return to the position where the string first became slack.
	Total time $=2+0.266...=2+\frac{4}{15}=2.27=\frac{34}{15}$ s	A1	
		4	

152. 9709_w19_MS_43 Q: 7

(i)	$\left[0.81 = 0 + \frac{1}{2} \times a \times 0.9^2\right]$	M1	For use of $s = ut + \frac{1}{2}at^2$
	$a = 2$	A1	
	$T - mg = ma$ **or** $kmg - T = kma$	M1	Use of Newton's Second Law for A or B or use of $a = \frac{(m_B - m_A)g}{(m_B + m_A)}$
	$T - mg = ma$ **and** $kmg - T = kma$ or $\left[a = \frac{(km - m)g}{(km + m)}\right]$	A1	
	$a = \frac{(kg - g)}{(k+1)} = 2 \rightarrow k = ...$	M1	Solves to find k
	$k = 1.5$	A1	
	$T = 10m + 2m = 12m$ N	B1	AG
		7	
(ii)	Velocity of A when string breaks $= 2 \times 0.9$ (=1.8 ms^{-1} upwards)	B1FT	For use of $v=u+at$ ft a from **(i)**
	$v^2=1.8^2+2g\times1.62 \rightarrow v=...$	M1	For use of *suvat* to find v_A at ground
	Speed is 5.97 ms^{-1}	A1	AG
	Time taken $= \frac{(1.8 + 5.97)}{g} = 0.777s$ (0.7769...)	B1	
		4	
(iii)	Straight line from (0, 0) to (0.9, 1.8)	B1	
	Straight line from (0.9, 1.8) to approx. (1.7, –6)	B1FT	FT 0.9 + t from **(ii)** for 1.7
		2	

153. 9709_m18_MS_42 Q: 1

	Answer	Mark	Partial Marks
	$[T - 2 = 0.2a$ $8 - T = 0.8a]$ System is $0.8g - 0.2g = (0.2 + 0.8)a$ and $T = 2(0.2)(0.8)g/(0.8 + 0.2)$	M1	Attempt Newton's 2nd law for either particle or use a formula for the system for a and/or T
		A1	Two correct equations
	Attempt to solve for a or T	M1	
	$a = 6$ $T = 3.2$	A1	Both correct NB $a = 6$ **AG**
		4	

154. 9709_m18_MS_42 Q: 4

	Answer	Mark	Partial Marks
	$[R = 12g \cos 25 + P \sin 25$ $P \cos 25 = F + 12g \sin 25]$ or $[P = F \cos 25 + R \sin 25$ $R \cos 25 = F \sin 25 + 12g]$	**M1**	Attempt resolving of forces in any one direction, parallel to, perpendicular to plane or horizontally, vertically
		A1	Any one correct equation
		A1	Any second correct equation
	$F = 0.8R$	**M1**	Use of $F = \mu R$
	Complete method to find P from 2 equations(3 terms each)	**M1**	
	$P = 242$	**A1**	
		6	

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155. 9709_s18_MS_41 Q: 3

	Answer	Mark	Partial Marks
(i)		**M1**	Attempt to resolve forces along the plane (2 terms)
	$100 \cos \theta = 8g \sin 30 \rightarrow \theta = 66.4$	**A1**	
	$[R = 8g \cos 30 + 100 \sin \theta]$	**M1**	Resolve forces perpendicular to the plane (3 terms)
	$R = 161$	**A1**	
		4	
(ii)	$100 \cos 30 - 8g \sin 30 = 8a$	**M1**	Apply Newton's 2nd law parallel to the plane (3 terms)
	$a = 5.83$	**A1**	
		2	

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156. 9709_s18_MS_42 Q: 7

	Answer	Mark	Partial Marks
(i)	$[T = 1.6a,\ 2.4g \sin 30 - T = 2.4a]$ System is $2.4g \sin 30 = 4a$	M1	Attempt Newton's 2nd law for A or B or for the system
		A1	Two correct equations
		M1	Solve for a or T
	$a = 3$	A1	
	$T = 4.8$	A1	
		5	
(ii)	Friction force on A is $F = 0.2 \times 1.6g\ [= 3.2]$	B1	From $F = \mu R$
	$T - F = 1.6a$ $2.4g \sin 30 - T = 2.4a$ System is $2.4g \sin 30 - F = 4a$	M1	Attempt Newton's 2nd law for both particles or for the system
		A1	Correct equations for A and B or correct system equation
		M1	Attempt to solve for a
	$a = 2.2$	A1	
	$v^2 = 2 \times 2.2 \times 1$	M1	Attempt to find v or v^2 when B reaches the barrier
	Subsequent acceleration of A is -2	B1	
	$4.4 = 2 \times 2 \times s$	M1	Attempt to find distance A travels while decelerating to $v = 0$
	Total distance travelled is 2.1 m	A1	
		9	
(ii)	**Alternative method for Q7 [Work-Energy applied to A and B]**		
	$F = 0.2 \times 1.6g\ [= 3.2]$	B1	From $F = \mu R = 0.2 \times 1.6g = 3.2$
		M1	Attempt PE loss as B reaches the barrier
	PE loss $= 2.4g \sin 30\ [= 12]$	A1	
		M1	Attempt KE gain for both A and B
	KE gain $= \frac{1}{2}(1.6 + 2.4)v^2\ [= 2v^2]$	A1	
	$[2.4g \sin 30 = \frac{1}{2} \times 4 \times v^2 + 3.2 \times 1]$ $[v^2 = 4.4]$	M1	Apply work-energy equation for the motion until B reaches the barrier (Three relevant terms)
	KE loss $= \frac{1}{2} \times 1.6 \times 4.4$	B1	Find KE loss as A comes to rest after B has stopped
	$[\frac{1}{2} \times 1.6 \times 4.4 = 3.2d]$ $[d = 1.1]$	M1	Apply work-energy equation where d is the extra distance travelled by A leading to a positive value for d
	Total distance = 2.1 m	A1	Distance $= d + 1$
(ii)	**Alternative scheme for first 6 marks of 7(ii) [Work-energy applied to A]**		
	Friction $= 0.2 \times 1.6g\ [= 3.2]$	B1	
	$[2.4g \sin 30 - T = 2.4a$ $T - F = 1.6a]$	M1	Apply Newton's 2nd law to A and B and solve for T
	$T = 6.72$	A1	
	$[\frac{1}{2} \times 1.6 \times v^2]$	M1	Attempt KE for A only
		A1	Correct KE for A
	$[6.72 \times 1 = \frac{1}{2} \times 1.6 \times v^2 + 3.2 \times 1]$	M1	Use work/energy equation for A
	Alternative scheme for first 6 marks of 7(ii) [Work-energy applied to B]		
	Friction $= 0.2 \times 1.6g\ [= 3.2]$	B1	
	$[2.4g \sin 30 - T = 2.4a$ $T - F = 1.6a]$	M1	Apply Newton's 2nd law to A and B and solve for T
	$T = 6.72$	A1	
		M1	Find energy loss/gain for B Allow [illegible]
	$\pm(\frac{1}{2} \times 2.4 \times v^2 - 2.4g \sin 30)$	A1	

157. 9709_w18_MS_41 Q: 1

	Answer	Mark	Partial Marks
	$4.5 = 2.5 + a \times 5$	M1	For use of $v = u + at$
	$a = 0.4$	A1	
	$F - 1.5 = 0.2a$	M1	For use of Newton's second law
	$F = 1.58$	A1	
		4	

158. 9709_w18_MS_41 Q: 4

	Answer	Mark	Partial Marks
(i)	$0.6^2 = 0 + 2a \times 0.8$	M1	For use of $v^2 = u^2 + 2as$
	$a = 0.225$	A1	
	$T - 0.3g = 0.3a$	M1	For using Newton's second law for the 0.3 kg particle
	$T = 3.07$ N (3.0675 N)	A1	
		4	
(ii)	$mg - T = ma$, $m(10 - 0.225) = 3.0675$	M1	For using Newton's second law applied to the m kg particle
	$m = 0.314$ kg (0.31381…)	A1	
		2	

159. 9709_w18_MS_41 Q: 6

	Answer	Mark	Partial Marks
(i)		M1	For using constant acceleration equations such as $s = ut + \frac{1}{2}at^2$ or equivalent complete methods to find expressions for PQ or QR or PR
	For PQ $0.8 = 0.6u + 0.18a$	A1	
	For PR $1.6 = 1.6u + 1.28a$	A1	or for QR $0.8 = (u + a \times 0.6) \times 1 + 0.5a$
		M1	Solving simultaneously two relevant equations in u and a
	Deceleration $= \frac{2}{3}$ ms^{-2}	A1	AG
	$u = \frac{23}{15}$	B1	
		6	
(ii)	$R = mg\cos 3$	B1	
	$F = \mu mg\cos 3$	M1	For use of $F = \mu R$
	$-mg\sin 3 - \mu \times mg\cos 3 = m \times \left(-\frac{2}{3}\right)$	M1	For using Newton's second law (3 terms)
	$\mu = 0.0144$ (0.014350…)	A1	
		4	

160. 9709_w18_MS_42 Q: 4

	Answer	Mark	Partial Marks
(i)	$T = 0.7g$	**B1**	
	$R = 0.4g \times {}^4/_5$ [$= {}^{16}/_5 = 3.2$]	**B1**	Normal reaction on particle P
	[$X + 0.4g \times {}^3/_5 - F - T = 0$]	**M1**	Attempt to resolve forces along the plane
	$X = 6.2$	**A1**	**AG**
		4	
(ii)	[$0.7g - T = 0.7a$] [$T - 0.8 - 0.4g \times {}^3/_5 - F = 0.4a$] [$0.7g - 0.8 - 0.4g \times {}^3/_5 - F = (0.7 + 0.4)a$] System	**M1**	For using Newton's 2nd law for both particle P and particle Q or the system equation
		A1	Both equations correct or system equation correct
		M1	Solve either the system equation or solve two simultaneous equations to find a
	$a = 2\text{ m s}^{-2}$	**A1**	
		4	

161. 9709_w18_MS_43 Q: 5

	Answer	Mark	Partial Marks
(i)	[$T - 0.3g = 0.3a$ or $0.5g - T = 0.5a$]	**M1**	Use of Newton's second law for P or Q or use of $a = (m_Q - m_P)g / (m_P + m_Q)$
	$T - 0.3g = 0.3a$ and $0.5g - T = 0.5a$ or $a = (0.5g - 0.3g) / (0.5 + 0.3)$	**A1**	
	[$0.5g - 0.3g = 0.8a$]	**M1**	Solve for a
	$a = 2.5$	**A1**	
	[$h = 0 + ½ \times 2.5 \times 0.6^2$]	**M1**	For use of $s = ut + ½at^2$
	$h = 0.45$	**A1**	
		6	
(ii)	Velocity of P when Q reaches floor $= 0 + 0.6 \times 2.5 = 1.5\text{ m s}^{-1}$	**B1ft**	ft a from **(i)** $\times 0.6$
	[$0 = 1.5 - gt \rightarrow t = \ldots$] ($t = 0.15$)	**M1**	Use of *suvat* to find time to highest point
	Total time $= 2 \times 0.15 + 0.6 = 0.9$ s	**A1**	
		3	

162. 9709_m17_MS_42 Q: 6

	Answer	Mark	Partial Marks
(i)		**M1**	Apply Newton's law to either of the particles
	$12 - T = 1.2a$ and $T - 8 = 0.8a$	**A1**	Both equations correct
		M1	Solve for a and T
	$a = 2\,\text{m s}^{-2}$ and $T = 9.6\,\text{N}$	**A1**	
	Total:	**4**	
(ii)	$[0.64 = ½ \times 2 \times t_1^2]$ $[v = 2t_1]$	**M1**	Attempt to find time t_1 taken for 1.2 kg particle to reach ground and/or its speed v at the ground
	$t_1 = 0.8$	**A1**	
	$v = 2 \times 0.8 = 1.6$	**A1**	
	$[0 = 1.6 - 10t_2]$ $[1.6^2 = 2 \times 10 \times s_2]$	**M1**	For attempting to find the time t_2 and/or distance travelled s_2 as 0.8 kg particle comes to rest
	$t_2 = 0.16$	**A1**	
	$s_2 = 0.128$	**A1**	
	$t_3 = 1 - 0.8 - 0.16 = 0.04$ $s_3 = ½ \times 10 \times 0.04^2$	**B1**	Finding the distance s_3 travelled downwards in t_3 seconds
	Total distance travelled = $0.64 + 0.128 + 0.008 = 0.776\,\text{m}$	**B1**	
	Total:	**8**	

163. 9709_s17_MS_41 Q: 2

	Answer	Mark	Partial Marks
(i)	$R = 0.8g \cos 10\ [= 7.88]$	**B1**	
	$F = 0.4 \times 8 \cos 10\ [= 3.15]$	**M1**	Use $F = \mu R$
	$-8 \sin 10 - 3.2 \cos 10 = 0.8a$	**M1**	Newton 2 along the plane
	$a = -5.68\ \text{ms}^{-2}$	**A1**	
	Total:	**4**	
(ii)	$0 = 12^2 - 2 \times 5.68 \times s$	**M1**	Using $v^2 = u^2 + 2as$
	$s = 144/(2 \times 5.68) = 12.7\,\text{m}$	**A1**	
	Total:	**2**	

164. 9709_s17_MS_41 Q: 7

	Answer	Mark	Partial Marks
(i)	[$T - 0.8g \sin 30 = 0.8a$ $1.2g \sin 60 - T = 1.2a$ $1.2g \sin 60 - 0.8g \sin 30 = 2a$]	M1	Resolve along the plane for either A or for B or for the system
	For A $T - 4 = 0.8a$	A1	
	For B $6\sqrt{3} - T = 10.4 - T = 1.2a$	A1	System equation is $6\sqrt{3} - 4 = 6.4 = 2a$
		M1	Solve for a or T
	$a = 3\sqrt{3} - 2 = 3.20$ ms^{-2}	A1	
	$T = \frac{12}{5}\left(1 + \sqrt{3}\right) = 6.56$ N	A1	
	Total:	6	
(ii)	$R_A = 0.8g \cos 30 = 4\sqrt{3}$ $R_B = 1.2g \cos 60 = 6$	B1	For either R_A or R_B
	$F_A = 4\sqrt{3}$ μ and $F_B = 6$μ	M1	Either F_A or F_B used
		M1	Resolve parallel to the plane for both particles A and B or system
	$12 \sin 60 - 6\mu - T = 0$ or $T - 8 \sin 30 - 4\sqrt{3}\,\mu = 0$	A1	System equation is $12 \sin 60 - 8 \sin 30 - 6\mu - 4\sqrt{3}\,\mu = 0$
		M1	Eliminate T and/or find μ
	$\mu = \left(6\sqrt{3} - 4\right) / \left(6 + 4\sqrt{3}\right)$ $= 0.494$	A1	
	Total:	6	

165. 9709_s17_MS_43 Q: 7

	Answer	Mark	Partial Marks
(i)	$R = mg\cos30$	B1	Resolves normally
	$F = 2m\cos 30$ $[= m\sqrt{3}]$	M1	Uses $F = \mu R$
	$T = 4g$ $[= 40]$	B1	Particle B
	$T = mg\sin30 + F$	M1	Resolves parallel to plane for particle A
	$40 = 5m + m\sqrt{3}$	A1	Equation in m
	$m = \dfrac{40}{5+\sqrt{3}} = 5.94$	A1	**AG** All correct and no errors seen
	Total:	6	
(ii)	*EITHER:* $[R = 3g\cos30]$ $F = 0.2 \times 3g\cos30$ $(3\sqrt{3} = 5.196)$	(B1	
	$4g - T = 4a$ or $T - 3g\sin30 - F = 3a$ or $4g - 3g\sin30 - F = 7a$	M1	Applies Newton's Second Law to one of the particles or forms system equation in a $(m_B g - m_A g\sin30 - F = (m_A + m_B)a)$
	$T - 3g\sin30 - 3\sqrt{3} = 3a$ or $40 - T = 4a$ or $4g - 3g\sin30 - 3\sqrt{3} = 7a \to a = \ldots$	M1	Applies Newton's Second Law to form second equation in T and a and solves for a or solves system equation for a
	$a = \dfrac{25 - 3\sqrt{3}}{7}$ $= 2.83.$	A1	
	$v^2 = 2 \times 2.83 \times 0.5$ $v = 1.68\ldots$	B1 FT	v as T becomes zero FT on a
	$-3g\sin30 - 0.2(3g\cos30) = 3a$ $-15 - 3\sqrt{3} = 3a$ $\to a = \ldots(-5-\sqrt{3} = -6.73)$	M1	Applies Newton's Second Law and solves for a
	$0 = 1.68^2 - 2 \times 6.73s$ $s = \ldots(0.210)$	M1	Uses $v^2 = u^2 + 2as$ and solves for s
	Total distance = 0.710 m	A1)	
	OR: $[R = 3g\cos30]$ $F = 0.2 \times 3g\cos30$ $(3\sqrt{3} = 5.196)$	(B1	
		M1	For 4kg mass, uses PE loss – WD_T = KE gain
		M1	For 3kg mass, uses WD_T = KE gain + PE gain + WD_{Fr}
	$4g(0.5) - 0.5T = ½(4v^2)$ and $0.5T = ½(3v^2) + 3g(0.5\sin30) + 3\sqrt{3}(0.5)$	A1	
	$v^2 = (25 - 3\sqrt{3})/7$ or $v = 1.68$	B1	
	$½(3)(1.68)^2 = 3g(s\sin30) + 3\sqrt{3}s$	M1	For 3kg mass, uses KE loss = PE gain + WD_{Fr}
	$s = \ldots(0.210)$	M1	Solves for s
	Total distance = 0.710 m	A1)	
	Total:	8	

166. 9709_w17_MS_41 Q: 1

	Answer	Mark	Partial Marks
	[12 cos 25 = 3a]	**M1**	For use of Newton's second law
	a = 4 cos 25 = 3.625	**A1**	
	[s = ½ × 4cos 25 × 5^2]	**M1**	For use of $s = ut + ½at^2$ OE
	Distance = 45.3 m	**A1**	
		4	

167. 9709_w17_MS_41 Q: 7

	Answer	Mark	Partial Marks
(i)		**M1**	For applying Newton's 2nd law to either particle (correct number of terms)
	T – 0.9 g sin 15 = 0.9a	**A1**	
	2.5 + 0.4 g sin 25 – T = 0.4a	**A1**	
	1.3a = 1.86…	**M1**	Solving simultaneously for a
	a = 1.43 m s^{-2}	**A1**	
		5	
(ii)	F = 0.8 × 0.4g cos 25	**B1**	
	2.5 + 0.4 g sin 25 – T – F = 0	**M1**	For using equilibrium of forces acting on particle B with 4 terms
	T – 0.9 g sin θ = 0	**M1**	For using equilibrium of forces acting on particle A with 2 terms
		M1	For solving for θ
	θ = 8.2°	**A1**	
		5	

168. 9709_w17_MS_42 Q: 1

	Answer	Mark	Partial Marks
(i)	$F = 0.2g \sin 20 = 0.684$ N	**B1**	AG
		1	
(ii)	$R = 0.2g \cos 20$	**B1**	
	$F = \mu R$ [$= 0.6 \times 0.2g \cos 20$]	**M1**	Using $F = \mu R$ $F = 1.1276\ldots$
	[$0.9 + 0.2g \sin 20 - F = 0.2a$]	**M1**	Use of Newton's 2nd law along the plane (4 relevant terms)
	$a = 2.28$ ms^{-2}	**A1**	
		4	

169. 9709_w17_MS_42 Q: 6

	Answer	Mark	Partial Marks
(i)	$R = mg\cos\alpha$ $(R = 9.6m)$	B1	Allow use of $\alpha = 16.3°$ throughout
	$[T = mg$ $F = mg\sin\alpha + T]$	M1	For resolving forces on P and Q and eliminating T **or** for considering the equilibrium of the system
	$F = mg\sin\alpha + mg$	A1	$(F = 12.8m)$
		M1	For use of $F = \mu R$
	Coefficient of friction = 1⅓ = $\frac{4}{3}$	A1	**AG** so must be from exact working
		5	
(ii)	*EITHER:* P equation is $10 - mg\sin\alpha - F - T = 2.5\,m$ Q equation is $T - mg = 2.5m$	(*M1	For applying Newton's 2nd law to P (5 terms) **or** Q (3 terms)
		*M1	For applying Newton's 2nd law to the other particle and eliminate T
	$10 - mg\sin\alpha - \mu mg\cos\alpha$ $- mg = 2m\,(2.5)$	A1	If evaluated then this is $10 - 2.8m - 12.8m - 10m = 5m$
		DM1	For solving this equation for m as far as $m =$ Dependent on one or other of the previous M marks having been scored
	$m = 0.327$	A1)	Allow $m = \frac{50}{153}$
	OR: $[10 - mg\sin\alpha - F - mg = m(2.5 + 2.5)]$	(*M1	For applying Newton's 2nd law to the system. Allow with 5 terms
		*M1	System equation with all 6 terms
	$10 - mg\sin\alpha - \mu mg\cos\alpha$ $- mg = 2m\,(2.5)$	A1	
		DM1	For solving this equation for m as far as $m =$ Dependent on one or other of the previous M marks having been scored
	$m = 0.327$	A1)	Allow $m = \frac{50}{153}$
		5	

170. 9709_w17_MS_43 Q: 3

	Answer	Mark	Partial Marks
(i)	$R = mg\cos 25$	B1	
	$[F = 0.4mg\cos 25]$	M1	Using $F = \mu R$
	$[mg\sin 25 - 0.4mg\cos 25 = ma]$	M1	Use of Newton's Second Law
	$a = 0.601\ \text{ms}^{-2}$	A1	
		4	
(ii)	$[s = \frac{1}{2} \times 0.601 \times 3^2]$	M1	Use of $s = ut + \frac{1}{2}at^2$
	Distance = 2.70 m	A1 FT	FT $4.5 \times a$ from **(i)**
		2	

171. 9709_m16_MS_42 Q: 4

	Answer		Mark		Partial Marks
(i)	$5\cos\alpha = F$	$[F = 4]$	M1		For resolving forces horizontally Allow use of $\alpha = 36.9°$ throughout
	$R + 5\sin\alpha = 8$	$[R = 5]$	M1		For resolving forces vertically
	$4 = 5\mu$		M1		For using $F = \mu R$
	$\mu = 0.8$		A1	4	
(ii)	$R + 10\sin\alpha = 8$ **and** $F = 0.8 \times R$	$[R = 2]$ $[F = 1.6]$	B1		For resolving forces vertically to find the new value of R **and** using $F = \mu R$
	$10\cos\alpha - F = 0.8a$		M1		For resolving horizontally
	$a = 8\ \text{ms}^{-2}$		A1	3	

172. 9709_m16_MS_42 Q: 6

	Answer	Mark		Partial Marks
(i)	[$T = 0.8a$ for A $2 - T = 0.2a$ for B $0.2g = (0.2 + 0.8)a$ system]	M1		For applying Newton's 2nd law either to particle A or to particle B or to the system
		M1		For applying N2 to a second particle (if needed) and solving for a
	[$a = 2$]	A1		
	[$2.5 = ½ \times 2 \times t^2$]	M1		A complete method for finding t such as using $s = ut + ½at^2$
	$t = 1.58$ s	A1	5	Allow $t = \frac{1}{2}\sqrt{10}$
First Alternative Method for 6(i)				
(i)	[$0.2 \times g \times 2.5$ or $½(0.2 + 0.8)v^2$]	M1		Finding PE loss or KE gain (system)
	[$0.2 \times g \times 2.5 = ½(0.2 + 0.8)v^2$]	M1		Using PE loss = KE gain and find v
	[$v^2 = 10$]	A1		
	[$2.5 = ½(0 + \sqrt{10})t$]	M1		For using $s = ½(u + v)t$
	$t = 1.58$ s	A1	5	Allow $t = \frac{1}{2}\sqrt{10}$

	Answer	Mark		Partial Marks
(i)	[$T = 0.8a$ $2 - T = 0.2a$ $\rightarrow T = 1.6$ N]	M1		Apply N2 to A and B and solve for T
	[$T \times 2.5 = ½ (0.8) v^2$]	M1		Use WD by T = KE gain by A, find v
	[$v^2 = 10$]	A1		
	[$2.5 = ½ (0 + \sqrt{10})t$]	M1		Using $s = ½(u + v)t$
	$t = 1.58$ s	A1	5	Allow $t = \frac{1}{2}\sqrt{10}$
(ii)	$N = 8$ and $F = 0.1 \times N = 0.8$	B1		
	$T - 0.8 = 0.8a$ and $2 - T = 0.2a$ or $0.2g - 0.8 = (0.2 + 0.8)a$	M1		For applying N2 to both particles or to the system and solving for a
	$a = 1.2$	A1		
	$v^2 = 0 + 2 \times 1.2 \times 2.5$	M1		For using $v^2 = u^2 + 2as$
	$v = \sqrt{6} = 2.45$ ms^{-1}	A1	5	
	First Alternative Method for 6(ii)			
(ii)	$N = 8$ and $F = 0.1 \times N = 0.8$	B1		
	[$0.2 \times g \times 2.5 = ½ (0.8 + 0.2) v^2 + 0.8 \times 2.5$]	M1		Apply work/energy to the system as PE loss = KE gain + WD against resistance
		A1		Correct Work/Energy equation
		M1		For solving for v
	$v = \sqrt{6} = 2.45$ ms^{-1}	A1	5	
	Second Alternative Method for 6(ii)			
(ii)	$N = 8$ and $F = 0.1 \times N = 0.8$	B1		
	$T - 0.8 = 0.8a$ and $2 - T = 0.2a$	M1		Use N2 for A and B and solve for T
	$T = 1.76$ N	A1		
	[$T \times 2.5 = 0.8 \times 2.5 + ½ (0.8) v^2$]	M1		Apply Work/Energy equation to A
	$v = \sqrt{6} = 2.45$ ms^{-1}	A1	5	

173. 9709_s16_MS_41 Q: 5

	Answer	Mark		Partial Marks
	$R = 5g\cos\alpha = 4g$ $F = 0.5 \times 4g = 2g$	**B1**		For finding the normal reaction R acting on the 5 kg particle and using $F = \mu R$
		M1		For applying Newton's second law to one or both particles or to the system
	$T - 2g - 5g\sin\alpha = 5a \rightarrow$ $T - 5g = 5a$	**A1**		System equation is $10g - 5g\sin\alpha - 2g = 5g = 15a$
	$10g - T = 10a$	**A1**		
	$[5g = 15a]$	**M1**		For eliminating T and solve for a
	$a = g/3 = 3.33\ \text{ms}^{-2}$	**A1**		
	$T = 10g - 10(g/3)$ $= 20g/3 = 66.7$ N	**B1**	[7]	

174. 9709_s16_MS_42 Q: 7

	Answer	Mark		Partial Marks
(i)	[$2.4g - T = 2.4a$ $T = 1.6a$ or the system equation $2.4g = (1.6 + 2.4)a$]	M1		For applying Newton's second law to one of the particles or to the combined system
		M1		For applying Newton's second law to a second particle if needed and/or solving for a
	$a = 6\text{ ms}^{-2}$	A1		
	$0.5 = ½ \times 6 \times t^2$	M1		For using $s = ut + ½at^2$
	$t = 0.408\text{s}$	A1	5	Accept $t = \sqrt{6}/6$
	Alternative for 7(i)			
(i)	[PE loss $= 2.4 \times g \times 0.5 = 12$ KE gain $= ½(1.6 + 2.4)v^2 = 2v^2$]	M1		For attempting to find PE and KE as B reaches the ground
	[$12 = 2v^2$]	M1		Using PE loss = KE gain
	$v^2 = 6 \rightarrow v = 2.45\text{ ms}^{-1}$	A1		
	[$0.5 = ½ \times (0 + 2.45) \times t$]	M1		Using $s = ½(u + v)t$
	$t = 0.408\text{s}$	A1	5	Accept $t = \sqrt{6}/6$
(ii)	$R = 1.6g = 16$ and $F = 3/8\ R = 6$	B1		
	System is [$2.4g - 6 = (1.6 + 2.4)a$]	M1		For using Newton's second law for both particles or the system
	$2.4g - T = 2.4a$ and $T - 6 = 1.6a$	A1		Both or system equation
	[$a = 4.5$]	M1		For finding a and using $v^2 = u^2 + 2as$ to find v as B reaches the ground
	$v = \sqrt{2 \times 4.5 \times 0.5} = \sqrt{4.5} = 2.12\text{ ms}^{-1}$	A1		
	$-6 = 1.6a \rightarrow a = -3.75\text{ ms}^{-2}$	M1		For finding the deceleration of A and using $v^2 = u^2 + 2as$ to find s the total distance travelled by A
	$0 = 4.5 + 2 \times (-3.75) \times (s - 0.5)$			
	$s = 1.1\text{ m}$	A1	7	

	Answer	Mark		Partial Marks
	First Alternative for 7(ii)			
(ii)	$R = 1.6g = 16$ and $F = 3/8\ R = 6$	**B1**		
		M1		For attempting PE loss **and** KE gain as B reaches the ground
	PE loss = $2.4 \times g \times 0.5[= 12]$ KE gain = $½ \times (1.6 + 2.4) \times v^2[= 2v^2]$	**A1**		For both PE and KE correct
		M1		For using PE loss = KE gain + WD against F
	$12 = 2v^2 + 6 \times 0.5 \rightarrow v^2 = 4.5 \rightarrow v = 2.12$	**A1**		
	Loss of KE = WD against F $[½ \times 1.6 \times 4.5 = 6 \times (s - 0.5)]$	**M1**		For considering the motion of A after B reaches the ground to find s the total distance travelled
	$s = 1.1$ m	**A1**	7	

175. 9709_w16_MS_41 Q: 2

	Answer	Mark		Partial Marks
(i)	$2 = 5a \rightarrow a = 0.4$ ms^{-2}	**B1**		
	$[0.1g \sin 20 - F = 0.1 \times 0.4]$	**M1**		For applying Newton's 2nd law to the particle
	$F = 0.302$ N AG	**A1**	[3]	
(ii)	$[R = 0.1g \cos 20\ \ (= 0.9397)]$	**M1**		For attempting to find R and using $\mu = F/R$
	$\mu = 0.3020/0.9397 = 0.321$	**A1**	[2]	

176. 9709_w16_MS_42 Q: 1

	Answer	Mark		Partial Marks
(i)	$3.5 = 10a \quad \rightarrow \quad a = 0.35\,\text{ms}^{-2}$	**B1**		Allow $a = 3.5/10$
	$[10\cos 15 - F = 2 \times 0.35]$	**M1**		For applying Newton's 2nd law to the particle
	$F = 8.96\,\text{N}$ AG	**A1**	[3]	
	Alternative to 1(i)			
	$s = ½\,(0 + 3.5) \times 10 = 17.5\,\text{m}$	**B1**		Distanced moved in 10 secs
	$[10\cos 15 \times 17.5 = F \times 17.5 + ½\,2\,(3.5)^2]$	**M1**		Work done by 10 N force = WD against F + KE gain
	$F = 8.96\,\text{N}$ AG	**A1**	[3]	
(ii)	$[R = 2g - 10\sin 15]$	**M1**		Resolving forces vertically
	$[\mu = 8.96/(2g - 10\sin 15)]$	**M1**		Using $F = \mu R$
	$\mu = 0.515$	**A1**	[3]	

177. 9709_w16_MS_43 Q: 3

	Answer	Mark		Partial Marks
(i)	$[7g - T = 7a$ **and** $T - 3g = 3a]$ or $[7g - 3g = 10a]$	**M1**		For applying Newton's second law to P **and** to Q or for using $m_Pg - m_Qg = (m_P + m_Q)a$
	Acceleration is $4\,\text{ms}^{-2}$	**A1**		
	$[v^2 = 0 + 2 \times 4 \times 0.4]$ $(v^2 = 3.2)$	**M1**		For using $v^2 = u^2 + 2as$
	Speed is $1.79\,\text{ms}^{-1}$	**A1**	[4]	
(ii)	$[0 = 3.2 + 2 \times (-g) \times s]$ $(s = 0.16)$	**M1**		For using $0 = u^2 + 2(-g)s$
	$0.16 + 0.4 = 0.56$ So particle Q does not come to rest before it reaches the pulley	**A1**	[2]	
	Alternative			
	$[v^2 = 3.2 + 2 \times (-g) \times 0.1]$	**M1**		For using $v^2 = u^2 + 2(-g)(0.1)$
	$v = \sqrt{1.2}$ $(= 1.10)$ So particle Q does not come to rest before it reaches the pulley	**A1**	[2]	

178. 9709_s15_MS_41 Q: 3

	Answer	Mark		Partial Marks
	$F = 0.25\left(6.1 \times \frac{60}{61}\right)$ [= 1.5]	B1		Allow $F = 0.25(6.1\cos 10.4)$
	[$W\sin\alpha - F = ma$]	M1		For using Newton's 2nd law
	$6.1 \times \left(\frac{11}{61}\right) - 0.25\left(6.1 \times \frac{60}{61}\right) = 0.61a$ or $6.1 \sin 10.4 - 0.25 \times 6.1 \cos 10.4 = 0.61a$	A1		$\left[a = -\frac{40}{61} = -0.656\right]$ The value of a may be seen but is not a required answer.
		M1		For using $0 = v_A^2 + 2as$
	Distance is $4 \div \left(2 \times \frac{40}{61}\right)$ = 3.05 m	A1	5	
	Alternative method			
	$F = 0.25\left(6.1 \times \frac{60}{61}\right)$ [= 1.5]	B1		Allow $F = 0.25(6.1 \cos 10.4)$
	KE loss = $\frac{1}{2} \times 0.61 \times 2^2$	B1		Finding loss of KE
	PE loss = $0.61 \times 10 \times x\left(\frac{11}{61}\right)$	B1		Finding loss of PE
	[$1.5x = 1.22 + 1.1x$]	M1		Using WD against F = KE loss + PE loss
	$0.4x = 1.22 \rightarrow$ distance = 3.05 m	A1	5	

179. 9709_s15_MS_41 Q: 7

	Answer	Mark		Partial Marks
(i)		M1		For using Newton's 2nd law for both particles
	$T - 0.2 \times 3 = 0.3a$ and $7 - T = 0.7a$	A1		
	Acceleration = 6.4 ms^{-2}	A1		
	[$v = 0 + 6.4 \times 0.25$]	M1		For using $v = 0 + at$ to find speed when string breaks
	$v = 1.6\ ms^{-1}$	A1		
	$\left[\text{Distance} = 0 + \frac{1}{2}6.4 \times 0.25^2\right]$	M1		For using $s = ut + \frac{1}{2}at^2$ to find distance moved before break
	Distance = 0.2 m	A1		
	[$v^2 = 1.6^2 + 2g \times (0.5 - 0.2)$]	M1		For using $v^2 = u^2 + 2gs$ to find speed when B hits floor
	Speed is 2.93 ms^{-1}	A1	9	
(ii)		M1		For finding distance travelled by A after break from $v^2 = u^2 + 2as$
	Distance travelled after break = $(0 - 1.6^2) \div (2 \times -2) = 0.64$	A1		For A, $F = 0.2 \times 3$ and so $-0.2 \times 3 = 0.3a$ so $a = -2$
	Total distance travelled = $0.2 + 0.64 = 0.84$	B1	3	Distance = 0.84 m
	Alternative method for 7(ii)			
(ii)	$T = 2.52$, $F = 0.2 \times 3$ WD by $T = 2.52 \times 0.2$ WD by $F = 0.2 \times 3 \times d$	B1		For stating WD by T on A and WD by F
	[$0.6d = 2.52 \times 0.2$]	M1		Using WD by F = WD by T (No change in KE or PE for A)
	WD by T = WD by $F \rightarrow d = 0.84$	A1	3	Distance = 0.84 m

180. 9709_s15_MS_42 Q: 6

	Answer	Mark		Partial Marks
(i)	$\left[h = \frac{1}{2} \times 0.5 \times 2\right]$	M1		For using area property of the graph or constant acceleration formulae
	$h = 0.5$	A1	2	
(ii)	$[a = 2 \div 0.5]$	B1		State the value of a using the gradient property of the graph
	$[T - mg = ma$ and $(1 - m)g - T = (1 - m)a$ or $a = \{(1 - 2m) \div (1 - m + m)\}g]$	M1		For applying both • Newton's 2nd law to P (while Q is moving) • Newton's 2nd law to Q (while Q is moving) or using $a = [(M - m) \div (M + m)]g$
		M1		For eliminating T or rearranging to find m
	$m = 0.3$	A1		
	$[T - 0.3 \times 10 = 4 \times 0.3$ or $0.7 \times 10 - T = 4 \times 0.7]$	M1		For substituting a and m into • Newton's 2nd law to P (while Q is moving) • Newton's 2nd law to Q (while Q is moving) to find T (tension)
	Tension is 4.2 N	A1	6	
(iii)		M1		For using the gradient property of the graph with acceleration $-g$
	$(-2 - 2) \div (t - 0.5) = -10$	A1		
	$T = 0.9$	A1	3	
	First Alternative method for (iii)			
(iii)	$[-2 = 2 - 10t]$	M1		For using $v = u + at$ to find the total time that string is slack
	$t = 0.4$	A1		
	Required time = 0.5 + 0.4 = 0.9	A1	3	
	Second Alternative method for (iii)			
(iii)	$t = 0.2$ s	B1		Obtaining the time taken from $v = 0$ to $v = 2$ OR $v = 0$ to $v = -2$
	$t = 0.2 \times 2 = 0.4$ s	B1		Obtaining the total time that the string is slack.
	Total time = 0.9 s	B1	3	For completing the solution using $0.4 + 0.5 = 0.9$ s

181. 9709_s15_MS_43 Q: 6

	Answer	Mark		Partial Marks
(i)		M1		For resolving forces down the plane
	$20 + 5g\sin10° - F = 0$	A1		
	$R = 5g\cos10°$	B1		
	$[\mu = (20 + 8.6824) \div 49.24]$	M1		For using $\mu = F \div R$
	Coefficient of friction is 0.582	A1	5	
(ii)		M1		For using Newton's 2nd law
	$5g\sin10° - 0.582 \times 49.24 = 5a$	A1√		ft μ from **(i)** ($\mu > 0$)
	$\left[0 = 2.5^2 - 2 \times 4s\right]$	M1		For using $v^2 = u^2 + 2as$
	Distance is 0.781 m	A1	4	
	Alternative Method for part (ii)			
(ii)	PE loss = $5gd\sin10°$	B1		
		M1		For using KE loss + PE loss = WD against friction
	$\frac{1}{2} \times 5 \times 2.5^2 + 5gd\sin10° = 0.582 \times 5gd\cos10°$	A1√		ft μ ($\mu > 0$)
	Distance is 0.781 m	A1	4	

182. 9709_w15_MS_41 Q: 2

	Answer	Mark		Partial Marks
(i)	$a = g\sin30 = 5$	**B1**		
	$2.5 = 0 + 5t$	**M1**		Using $v = u + at$
	$t = 0.5$ Time = 0.5 s	**A1**	3	
(ii)	$v^2 = 0 + 2 \times 5 \times 3 = 30$	**B1**		
	$-1 = 0.5a \rightarrow a = -2$			For applying Newton's second law to the particle and using
	$0 = 30 + 2 \times (-2) \times s$	**M1**		$v^2 = u^2 + 2as$
	Distance = 7.5 m	**A1**	3	
	First alternative method for 2(ii)			
	$v^2 = 0 + 2 \times 5 \times 3 = 30$	**B1**		
	$0.5 \times 0.5 \times 30 = 1 \times$ distance	**M1**		KE lost = WD against Friction
	Distance = 7.5 m	**A1**	3	
	Second alternative method for 2(ii)			
	PE lost = $0.5 \times 10 \times 3 \sin30 = 7.5$	**B1**		Using PE lost = mgh
	$7.5 = 1 \times$ distance	**M1**		PE lost = WD against Friction
	Distance = 7.5 m	**A1**	3	

183. 9709_w15_MS_41 Q: 3

	Answer	Mark		Partial Marks
(i)		**M1**		For applying Newton's second law to the lorry up the hill
	$F - 24000g \sin 3 - 3200 = 24000 \times (0.2)$	**A1**		[$F = 20561$]
	Power = $Fv = 20561 \times 25$	**M1**		Using $P = Fv$
	Power = 514 kW	**A1**	4	
(ii)	DF = $3200 + 24000g \sin 3$ [=15761]	**M1**		Using Newton's second law up the hill in the steady case
	$v = 500000/15761 = 31.7\ \text{ms}^{-1}$	**A1**	2	$P = Fv$ so $v = P/F$

184. 9709_w15_MS_41 Q: 5

	Answer	Mark		Partial Marks
(i)		M1		For resolving forces either horizontally or vertically
	$F\cos70 + 20 - 10\cos30 = R\cos15$	A1		
	$10\sin30 - F\sin70 = R\sin15$	A1		
		M1		For solving simultaneously
	$F = 1.90$ N **and** $R = 12.4$ N	A1	5	
	Alternative method for 5(i)			
	$[X = 0.342F + 11.34$ $Y = 0.94F - 5]$	M1		For finding components of the forces in the x and y directions
	$(0.342F + 11.34)^2 + (0.94F - 5)^2 = R^2$	A1		
	$\tan15 = (5 - 0.94F) / (0.342F + 11.34)$	A1		
		M1		Solve the tan 15 equation for F and substitute to find R
	$F = 1.90$ N **and** $R = 12.4$ N	A1	5	
(ii)	$11.7^2 = 0 + 2a \times 3$			
	$a = 22.815$	B1		
	$R\cos15 = m \times 22.815$	M1		Applying Newton's second law to the particle in direction AB
	Mass of bead = 0.526 kg	A1	3	

185. 9709_w15_MS_42 Q: 5

	Answer	Mark		Partial Marks
(i)		M1		For applying Newton 2^{nd} law to P **or** to Q **or** for applying N2 to the system
	$0.5g \times \frac{7}{25} - T = 0.5a$ $T - 0.1g = 0.1a$ $1.4 - 1 = 0.6a$	A1		Any two correct Allow sin 16.3 for 7/25
	For eliminating T and obtaining $a = \frac{2}{3}$ ms^{-2}	B1		
		M1		For substituting for a to find T
	Tension is 1.07 N	A1	5	Allow $T = 16/15$ N
(ii)	$[v^2 = 2 \times \left(\frac{2}{3}\right) \times 0.7]$	M1		For using $v^2 = u^2 + 2as$ to find the speed of the particles immediately before the string breaks
	$[2^2 = 2 \times \frac{2}{3} \times 0.7 + 2 \times 0.28g \times s]$	M1		For applying $v^2 = u^2 + 2as$ for the motion of P when the string is slack and s is the distance travelled by P after the break until it reaches the floor
	Length of string $= 2.5 - s = 1.95$ m	A1	3	Allow length = 41/21 m

186. 9709_w15_MS_42 Q: 6

	Answer	Mark		Partial Marks
(i)	$[0.195 \cos \theta = F]$	**M1**		For resolving forces horizontally
	$F = 0.195\cos 22.6 = 0.195 \times \frac{12}{13}$			
	$= 0.18 = \frac{9}{50}$	**A1**		
	$[R = 0.24 + 0.195 \sin \theta]$	**M1**		For resolving forces vertically
	$R = 0.24 + 0.195\sin 22.6 = 0.24 + 0.195 \times \frac{5}{13} = 0.315$			
	$= \frac{63}{200}$	**A1**		
		M1		For using $\mu = F/R$
	Coefficient $\mu = 4/7$ or 0.571	**A1**	6	
(ii)	$R = 0.24 - 0.195\sin 22.6$			
	$= 0.24 - 0.195 \times \frac{5}{13}$			
	$= 0.165 = \frac{33}{200}$	**B1**		
		M1		For using Newton's second law for motion along the rod
	$0.195 \times \frac{12}{13} - \left(\frac{4}{7}\right) \times 0.165$			
	$= 0.024a$	**A1**		
	Acceleration is $3.57\ \text{ms}^{-2}$	**A1**	4	Allow acceleration = 25/7

187. 9709_w15_MS_43 Q: 4

	Answer	Mark		Partial Marks
(i)		M1		For applying Newton's second law to A or to B or for using $m_Ag - m_Bg = (m_A + m_B)a$
	$0.35g - T = 0.35a$ $T - 0.15g = 0.15a$ $(0.35 - 0.15)g = (0.35 + 0.15)a$	A1		Two of the three equations
	Acceleration is 4 ms^{-2}	B1		
	Tension is 2.1 N	B1	4	
(ii)	$[v_1^2 = 0 + 8 \times 1.6 (= 12.8)]$	M1		For using $v_1^2 = 0 + 2a \times 1.6$
	$[H = 1.6 + (-12.8) \div (-20)]$	M1		For using $H = 1.6 + (0 - v_1^2)/(-2g)$ or for using $h = (0 - v_1^2)/(-2g)$
	Greatest height is 2.24 m	A1	3	

188. 9709_s20_MS_41 Q: 2

(a)	$[T - 100 = 400 \times 1.5]$	M1
	$T = 700$ N	A1
		2
(b)	$F - 250 - 100 = 2200 \times 1.5$ ($F = 3650$ N) (**M1** for using Newton's second law for the system or for the car using the result from **2(a)**)	M1
	For use of power $= Fv$	M1
	73 000 W or 73 kW	A1
		3

189. 9709_s20_MS_41 Q: 5

(a)	Attempt at finding PE lost	M1
	PE lost $= 35g$ (4cos22.5 – 4cos45)	A1
	$\frac{1}{2} \times 35v^2 = 35g$ (4cos22.5 – 4cos45)	M1
	Speed $= 4.16$ ms^{-1} (4.1643...)	A1
		4
(b)	Use of the work-energy equation in the form: PE lost = KE gain + WD against resistance	M1
	$\frac{1}{2} \times 35 \times 4^2 = 35g(4 - 4\cos 45) - X$	A1
	$X = 130$ (130.05...)	A1
		3

190. 9709_s20_MS_42 Q: 4

(a)	$4\times10\,[+0]=4\times0.5v+2v$	M1
	$v_A=5$ and $v_B=10$	A1
		2
(b)	Conservation of momentum *B*, *C* $2\times10\,[+0]=2\times v+3v$	M1
	$v=4$	A1
	$v_A>v_B$, hence another collision	A1
		3
(c)	Conservation of momentum *A*, *B*	M1
	$4\times their5+2\times their4=4v+2v \quad v=\frac{14}{3}\ (\mathrm{ms}^{-1})$	A1
	KE initial $=\frac{1}{2}\times4\times10^2$	M1
	KE final $=\frac{1}{2}\times6\times their\,(\frac{14}{3})^2+\frac{1}{2}\times1\times their\,12^2$	A1
	Loss of KE $=200-\frac{412}{3}=\frac{188}{3}$	A1
		5

191. 9709_s20_MS_42 Q: 5

(a)(i)	$DF=750$	B1
	Power $=their(750)\times32$ $=24\mathrm{kW}$	B1 FT
		2
(a)(ii)	$16000=DF\times32$ $DF=500$	M1
	$500-750=1250\times a$	M1
	$a=[-]0.2$	A1
		3
(b)	$DF=1000+8v+1250\times10\times0.096$	M1
	$2200+8v$	A1
	$60000=(2200+8v)v$	M1
	$8v^2+2200v-60000=0$	A1
	$v=25$	A1
		5

192. 9709_s20_MS_43 Q: 5

(a)	Decrease in KE $= \frac{1}{2} \times 4 \times (12^2 - 8^2)$	M1
	160 J	A1
		2
(b)	PE gained $= 4g \times 10\sin 30$ $(= 200)$	B1
	Total work done $= 200 - 160$	M1
	Total work done $= 40$ J	A1 FT
		3
(c)	$-4g\sin 30 = 4a$	M1
	$a = -5$	A1
	$-10 = 8t - \frac{1}{2} \times 5t^2$	M1
	$t = 4.16$ s	A1
		4

193. 9709_W20_MS_41 Q: 1

	Answer	Mark	Partial Marks
(a)	$6 \times 2.5 = 2.5v + 5v$	M1	Apply conservation of momentum, 3 terms implied
	$v = 2\ \text{ms}^{-1}$	A1	
		2	
(b)	Use KE = ½ mv^2 either before or after collision	M1	Allow this for either particle
	KE(before) $= 0.5 \times 2.5 \times 6^2$ KE(after) $= 0.5 \times 7.5 \times 2^2$	A1 FT	Both correct FT on v
	Loss of KE = 30 J	A1	
		3	

194. 9709_W20_MS_41 Q: 6

	Answer	Mark	Partial Marks
(a)	KE (final) = ½ × 1500 × 20^2 + ½ × 750 × 20^2 KE (initial) = ½ × 1500 × 30^2 + ½ × 750 × 30^2	B1	Use KE = ½mv^2 for any two of the four elements
	PE gain = 2250 × 10 × 800 × 0.08	B1	
	WD against friction = 600 × 800	B1	
	½ × 2250 × 30^2 + DF × 800 = 600 × 800 + ½ × 2250 × 20^2 + 2250 × 10 × 800 × 0.08	M1	Use energy equation.
	DF = 1700 N	A1	DF = 1696.875 N
		5	
(b)	2400 – 600 = 2250a or T – 200 = 750a **and** 2400 – 400 – T = 1500a	M1	Apply Newton's second law to the system or to each of the car and trailer separately
		A1	Two correct equations
	Attempting to solve for a or for T	M1	
	T = 800 N and a = 0.8 ms^{-2}	A1	
		4	

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195. 9709_W20_MS_42 Q: 2

	Answer	Mark	Partial Marks
(a)	DF – 650 = 1800 × 0.5 [DF = 1550]	M1	Apply Newton's second law, 3 terms
	$\frac{P}{20} - 650 = 1800 \times 0.5$	B1	
	[Power P = 1550 × 20 =] 31 000 W or 31 kW	A1	
		3	
(b)	$\frac{31000}{v} - 650 = 0$	M1	Use $P = Fv$ with F = 650
	v = 47.7 ms^{-1}	A1 FT	FT on *their* $P \neq$ 13 000 Allow $\frac{620}{13}$
		2	

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196. 9709_W20_MS_42 Q: 8

	Answer	Mark	Partial Marks
(a)	For A: $T = 0.3a$ For B: $3.5 + 0.5g \sin 30 - T = 0.5a$ System: $3.5 + 0.5g \sin 30 = (0.3 + 0.5)a$	M1	For applying Newton's 2nd law for either particle A or to particle B or to the system. Correct number of terms.
		A1	Two correct equations
	For solving either for T or for a	M1	
	$a = 7.5 \text{ ms}^{-2}$	A1	
	$T = 2.25$ N	A1	
		5	
(b)	$0.5g \sin 30 \times 0.6$ [= 1.5]	B1	PE loss by B
	Apply the work-energy equation to the system	M1	5 relevant terms, their PE for 0.5 kg, WD by 3.5 N, WD against friction and two relevant KE terms.
	$0.5g \sin 30 \times 0.6 + 3.5 \times 0.6 = \frac{1}{2} \times 0.8 \times v^2 + 1.1$	A1	
	$v = 2.5 \text{ ms}^{-1}$	A1	
		4	

197. 9709_W20_MS_43 Q: 2

	Answer	Mark	Partial Marks
(a)	$WD = 40 \times 158 = 600$ J	B1	
		1	
(b)	[$PE = 5 \times 10 \times 15 \sin 20$]	M1	Attempt PE gain
	257 J (256.5151... J)	A1	
		2	
(c)	$WD = 40 \times 15 + 5 \times 10 \times 15 \sin 20 = 857$ J	B1 FT	FT 600 + 'PE'(> 0) from **2(b)**
		1	

198. 9709_W20_MS_43 Q: 4

	Answer	Mark	Partial Marks
	For using conservation of momentum (either case)	M1	
	$6 \times 4 = 3m + 4 \times 1.5$ **or** $6 \times 4 = 3m - 4 \times 1.5$	A1	
	$m = 6$ **and** $m = 10$	A1	
	KE_A initial $= \frac{1}{2} \times 4 \times 6^2$ (72 J) or KE_A after $= \frac{1}{2} \times 4 \times 1.5^2$ (4.5 J) or KE_B after $= \frac{1}{2} \times 6 \times 3^2$ (27 J) or KE_B after $= \frac{1}{2} \times 10 \times 3^2$ (45 J)	B1 FT	$KE = \frac{1}{2} \times m \times v^2$ FT $4.5m$ for KE_B
	KE loss = [$\frac{1}{2} \times 4 \times 6^2 - \frac{1}{2} \times 4 \times 1.5^2 - \frac{1}{2} \times 6 \times 3^2$] or [$\frac{1}{2} \times 4 \times 6^2 - \frac{1}{2} \times 4 \times 1.5^2 - \frac{1}{2} \times 10 \times 3^2$]	M1	Uses KE loss = KE before – KE after
	Loss of KE = 40.5 J or 22.5 J	A1	
		6	

199. 9709_W20_MS_43 Q: 6

	Answer	Mark	Partial Marks
(a)(i)	$P = 650 \times 25$	**M1**	Use $P = Fv$ with F = total resistance
	$P = 16\,250$ W = 16.25 kW	**A1**	Accept 16 300 W or 16.3 kW (3sf)
		2	
(a)(ii)	$\text{DF} = \dfrac{39000}{25}$ (= 1560)	**B1**	For using DF = P/v
	For applying Newton's 2nd law to the system to form an equation in a, or to the caravan or the car to form an equation in T and a	**M1**	[$1560 - 650 = 2400 \times a$]
	$1560 - 650 = 2400a$ $T - 250 = 800a$ $1560 - 400 - T = 1600a$	**A1**	Two correct equations
	$\left[a = \dfrac{(1560-650)}{2400}\right]$	**M1**	For solving for a or for T
	$a = 0.379$ ms^{-2} (0.37916…) $T = 553$ N (553.33…)	**A1**	
		5	
(b)	[$\text{DF} = 650 + 2400 \times 10 \times 0.05$]	**M1**	Newton's 2nd law
	$32\,500 = (650 + 24\,000 \times 0.05)v$	**M1**	For using $P = Fv$
	$v = 17.6$	**A1**	Allow $v = \dfrac{650}{37}$
		3	

200. 9709_m19_MS_42 Q: 4

	Answer	Mark	Partial Marks
(i)	Driving force = 6000/20 [= 300 N]	**B1**	Using $F = P/v$
	$R = 300 - 80 = 220$	**B1ft**	Net force on system = $300 - R - 220 = 0$ ft on DF found
		2	
(ii)	[New driving force DF = 12500/25 = 500 N Car: DF – T – R = 1500a Trailer: T – 80 = 300a System: DF – 80 – R = 1800a]	**M1**	Any one equation from the following: Apply Newton's 2nd law to the car Apply Newton's 2nd law to the trailer Apply Newton's 2nd law to the system of car and trailer.
	Two correct equations	**A1ft**	Correct DF = 500 must be used. ft on R value found
		M1	EITHER solve two dimensionally correct simultaneous equations in a and T to find a or T OR solve the system equation to find a
	$a = 0.111$ m s^{-2}	**A1**	Allow $a = 1/9$
	$T = 113$ N (= 113.3333...)	**A1**	Allow $T = 340/3$
		5	

201. 9709_m19_MS_42 Q: 7

	Answer	Mark	Partial Marks
(i)	$R = 0.25g \times 0.6$ [= 1.5]	B1	
	[$F = 0.5 \times 0.25g \times 0.6$] [$F = 0.75$]	M1	Use $F = \mu R$
	[WD against friction = $F \times 8$]	M1	Using WD = Force × distance moved in direction of force
	WD = 6 J	A1	
		4	
(ii)	[$\frac{1}{2} \times 0.25 \times 15^2 =$ $\frac{1}{2} \times 0.25 \times v^2 + 6 + 0.25g \times 8 \times 0.8$]	M1	Work-energy equation in the form Initial KE = Final KE + WD against F + PE gain
		A1ft	Correct Work–Energy equation for the motion to Q. ft on WD
		M1	Solving the work-energy equation for v
	$v = 7$ m s^{-1}	A1	
	Alternative method for question 7(ii)		
	[$-F - 0.25g \sin\alpha = 0.25a$]	M1	Applying Newton's second law to the particle along the plane
	$a = -11$ m s^{-2}	A1ft	ft on friction found in (i)
		M1	Finding the speed of the particle at Q by applying $v^2 = u^2 + 2as$ with $u = 15$, $s = 8$ or equivalent complete method
	$v = 7$ m s^{-1}	A1	
		4	
(iii)	[$\frac{1}{2} \times 0.25 \times 7^2 = 0.25 \times g \times H$] Or [$\frac{1}{2} \times m \times 7^2 = m \times g \times H$]	M1	KE lost from Q to R = PE gain from Q to R H is the height of R above Q
	$H = 7^2/2g = 2.45$ m	A1	
	Total height $h = 6.4 + H = 8.85$	A1	
	Alternative method for question 7(iii)		
	[$\frac{1}{2} \times 0.25 \times 15^2 = 6 + 0.25g \times h$]	M1	Work-energy from P to R
		A1	Correct Work-energy equation from P to R
	$h = 8.85$	A1	
		3	

202. 9709_s19_MS_41 Q: 3

	Answer	Mark	Partial Marks
(i)	DF = 1500 □ 12 000 □ g □ 0.08 [DF = 11100]	**M1**	Using DF = Resistance □ weight component (3 terms)
	Power = DF □ 5	**M1**	Using $P = Fv$ (their 2 term DF □ 5)
	Power = 11 100 □ 5 = 55.5 kW	**A1**	**AG**
		3	
(ii)	k □ 5^2 = 1500, k = 60	**B1**	**AG**
		1	
(iii)	DF = $60v^2$	**B1**	Using DF = resistance = $60v^2$
	55500 = DF □ v = $60v^2$ □ v = $60v^3$	**M1**	$P = Fv$ used and attempt to solve a 2-term cubic equation for v
	v = 9.74 ms^{-1}	**A1**	
		3	

203. 9709_s19_MS_41 Q: 4

	Answer	Mark	Partial Marks
(i)	R = 13 cos 67.4 = 13 (5/13) [R = 5]	**B1**	Resolve forces perpendicular to plane. Allow 67.4 used
	F □ 13 sin 67.4 = F + 13(12/13) = 20 [F = 8]	**B1**	Resolve forces parallel to plane. Allow 67.4 used
		M1	Use $F = \mu R$
	μ = 8/5 = 1.6	**A1**	**AG** Must be from exact working here
		4	
(ii)	13 sin 67.4 – F = 1.3a $F = \mu R$ = 8 → [4 = 1.3a]	**M1**	For applying Newton's second law along the plane and also using $F = \mu R$ (3 terms)
	a = 3.08 ms^{-2}	**A1**	Allow a = 40/13
		2	
(iii)	s = 0 □ 0.5 □ (40/13) □ 2^2 [= 80/13 = 6.15]	**M1**	Use $s = ut$ □ ½at^2 with u = 0 and their $a \neq \pm g$ to find the distance moved in the first 2 seconds
	WD = 8 □ 6.15	**M1**	WD = F □ d
	WD = 49.2 J	**A1**	Allow WD = 640/13 J
	Alternative method for question 4(iii)		
	s = 0 □ 0.5 □ (40/13) □ 2^2 [= 80/13 = 6.15]	**M1**	
	[v = (40/13) × 2] and [WD = 1.3g(80/13)(12/13) – ½ □ 1.3 □ $(80/13)^2$]	**M1**	Finding v after 2 seconds and using WD = PE loss – KE gain
	WD = 49.2 J	**A1**	Allow WD = 640/13 J
		3	

204. 9709_s19_MS_41 Q: 6

	Answer	Mark	Partial Marks
(i)	Particle A: $T = 4\sin\theta$ Particle B: $T = 2$	**M1**	Resolve forces for A and for B
		M1	Eliminate T and solve for θ
	$\theta = 30$	**A1**	
		3	
(ii)(a)	A: $T - 4\sin 20 = 0.4a$ B: $2 - T = 0.2a$ System: $2 - 4\sin 20 = (0.4 □ 0.2)a$	**M1**	Apply Newton's second law to A or to B or to the system
		A1	Two correct equations
		M1	Solve for a or T
	$T = 1.79$ and $a = 1.05$	**A1**	Both correct
		4	
(ii)(b)	$v^2 = 2 □ 1.053 □ 0.5 = 1.053$	**M1**	Attempt to find v using their $a \neq \pm g$
	$v = 1.03\ \text{ms}^{-1}$	**A1**	
		2	
(ii)(c)	Loss in KE = ½ □ 0.4 □ 1.053 = 0.2106 Gain in PE = 0.4 □ 10 □ d sin 20	**M1**	Attempt KE loss or PE gain for particle A only after particle B hits the ground.
		A1ft	Both correct, d is distance moved up the plane after B hits ground
	½ □ 0.4 □ 1.053 = 0.4 □ 10 □ d sin 20	**M1**	Apply KE loss = PE gain
		A1	**FT** Correct energy equation
	Total dist A moves up plane = 0.5 □ d = 0.654 m	**A1**	
		5	

205. 9709_s19_MS_42 Q: 3

	Answer	Mark	Partial Marks
	$R = 13g\cos 22.6 = 13g \times (12/13)$, $[R = 120]$	**B1**	Resolve perpendicular to the plane
	$F = 0.3 \times 13g\cos 22.6$ $[F = 36]$	**M1**	Using $F = \mu R$
	$T = F + 13g\sin 22.6 = F + 13g \times (5/13)$, $[T = 86]$	**M1**	Apply Newton's second law parallel to the plane with $a = 0$
	WD = $T \times 2.5$ [= 86×2.5]	**M1**	WD = $T \times d$
	WD = 215 J	**A1**	
	Alternative method for question 3		
	$R = 13g\cos 22.6 = 13g \times (12/13)$, $[R = 120]$	**B1**	Resolve perpendicular to the plane
	$F = 0.3 \times 13g\cos 22.6$ $[F = 36]$	**M1**	Using $F = \mu R$
	PE gain = $13 \times g \times 2.5 \times (5/13)$ [= 125]	**M1**	Attempt PE gain. Allow sin 22.6 for 5/13
	[WD by $T = 13 \times g \times 2.5 \times (5/13) + F \times 2.5$]	**M1**	Using WD by T = PE gain + WD against F
	WD by T = 215 J	**A1**	
		5	

206. 9709_s19_MS_42 Q: 6

	Answer	Mark	Partial Marks
	Case 1: DF = 36000/18 or Case 2: DF = 21000/12	**B1**	DF = P/v in either case
	$18A + B$ = DF [$36000/18 = 18A + B = 2000$]	**M1**	Use DF = resistance (case 1)
	$18A + B = 2000$ oe	**A1**	Correct equation, unsimplified
	$12A + B$ = DF + weight component [$21000/12 = 12A + B + 1000g \times 1/20$]	**M1**	Use DF = resistance + weight component (case 2)
	$12A + B = 1250$ oe	**A1**	Correct equation, unsimplified
		DM1	Solve two simultaneous equations in A and B only for A or B Dependent on both previous M1's
	$A = 125$, $B = -250$	**A1**	Both correct
		7	

207. 9709_s19_MS_43 Q: 3

	Answer	Mark	Partial Marks
(i)		**M1**	Use of Newton's Second Law (4 terms)
	$DF - 1550 - 1400g\sin 4° = 1400 \times 0.4$	**A1**	($DF = 3086.59...$)
	[$30000 = (1400 \times 0.4 + 1550 + 1400g\sin 4°)v$]	**M1**	Use of $P = Fv$
	$v = 9.72\ \text{ms}^{-1}$	**A1**	
		4	
(ii)	[$DF - 1550 - 1400g\sin 4° = 0$]	**M1**	($DF = 2526.59...$) Resolving up the hill
	[$P_{max} = (1550 + 1400g\sin 4°) \times 40$]	**M1**	Use of $P = Fv$
	$P = 101000$ W or 101 kW	**A1**	($P = 101063.6...$)
		3	

208. 9709_s19_MS_43 Q: 5

	Answer	Mark	Partial Marks
(i)	(PE gain =) $18gd\sin 30°$ **or** (KE loss =) $½ \times 18 \times 20^2$	**B1**	
	(PE gain =) $18gd\sin 30°$ **and** (KE loss =) $½ \times 18 \times 20^2$	**B1**	
	[$18gd\sin 30° = ½ \times 18 \times 20^2$] **or** [$18gh = ½ \times 18 \times 20^2$]	**M1**	Energy equation (PE gain = KE loss)
	Distance up plane = 40 m	**A1**	
		4	
(ii)	$R = 18g\cos 30°$ ($90\sqrt{3}$ or 155.884...)	**B1**	
	[$F = 0.25(18g\cos 30°)$] ($45\sqrt{3}/2$ or 38.971...)	**M1**	Use of $F = \mu R$
	[$18g\sin 30° + 0.25(18g\cos 30°) = -18a \rightarrow a = ...$] ($a = -7.165..$)	**M1**	Newton's Second Law (3 term equation)
	[$0^2 = 20^2 + 2 \times -7.165.. \times s \rightarrow s = ...$]	**M1**	Use of *suvat* to find s
	$s = 27.913...$	**A1**	
(ii)	[$18g\sin 30° - 0.25(18g\cos 30°) = 18a \rightarrow a = ...$]	**M1**	($a = 2.835..$) – Newton's Second Law (3 term equation)
	[$v^2 = 0^2 + 2 \times 2.835.. \times 27.913.. \rightarrow v = ...$]	**M1**	Use of *suvat* to find s
	$v = 12.6\ \text{ms}^{-1}$	**A1**	(12.580...)
	Alternative Method 1 for 5(ii)		
	$R = 18g\cos 30°$ ($90\sqrt{3}$ or 155.884...)	**B1**	
	[$F = 0.25(18g\cos 30°)$] ($45\sqrt{3}/2$ or 38.971...)	**M1**	Use of $F = \mu R$
	[KE gain = $½ \times 18 \times 20^2$ and PE loss = $18gh$ or $18gs(\sin 30°)$]	**M1**	Use of KE = $1/2\ mv^2$ and PE = mgh
	[$½ \times 18 \times 20^2 = 18gs(\sin 30°) + 45\cos 30° \times s$]	**M1**	Work / Energy equation (up plane)
	$s = 27.913...$	**A1**	
	[WD = $45\cos 30° \times 27.91...$]	**M1**	Work done against friction
	[$½ \times 18v^2 = (18g\sin 30°) \times 27.91.. - 45\cos 30° \times 27.91...$]	**M1**	Work / Energy equation (down plane)
	$v = 12.6\ \text{ms}^{-1}$	**A1**	(12.580...)
	Alternative Method 2 for 5(ii) (last 3 marks)		
	[WD = $2 \times 45\cos 30° \times 27.91...$]	**M1**	WD against friction (up and down)
	[$½ \times 18 \times 20^2 - ½ \times 18v^2 = 2 \times 45\cos 30° \times 27.91...$]	**M1**	Uses KE loss = total WD against friction
	$v = 12.6\ \text{ms}^{-1}$	**A1**	(12.580...)
		8	

209. 9709_w19_MS_41 Q: 1

	Answer	Mark	Partial Marks
	$20\,000 = V \times 1250g$	**M1**	Use of $P = Fv$ with $F = mg$
	$V = 1.6$	**A1**	
		2	

210. 9709_w19_MS_41 Q: 2

	Answer	Mark	Partial Marks
	Initial $KE = \frac{1}{2} \times 75 \times 10^2$ Final $KE = \frac{1}{2} \times 75 \times 5^2$	B1	Either correct
	PE gained $= 75g \times 700 \sin 1.5$ [=13 743]	B1	
	WD by $F = F \times 700$	B1	For WD by $F = F \times d$
	WD by F + Initial KE = Final KE + PE gain + 2000	M1	Use of work-energy equation. 5 dimensionally correct terms.
	$F = 18.5$	A1	
		5	

211. 9709_w19_MS_42 Q: 4

	Answer	Mark	Partial Marks
(i)	$P = 3000 \times 30$	M1	Use of $P = Fv$ with F = resistance
	$P = 90000$ W = 90kW	A1	
		2	
(ii)	PE gained = $25000gh$	B1	Correct expression for PE Allow PE = 25 000 g d sin 2
	Initial KE $= \frac{1}{2} \times 25000 \times 30^2$ [= 11 250 000] Final KE $= \frac{1}{2} \times 25000 \times 25^2$ [= 7 812 500]	B1	For either correct [KE loss = 3 437 500]
	Initial KE = Final KE + $25000gh + \frac{3000h}{\sin 2}$ OR Initial KE = Final KE + $25000gd\sin 2 + 3000d$	M1	For a 4 term work-energy equation, correct dimensions
		A1	Correct work-energy equation involving h or d
	$h = 10.2$ m (10.2318…)	A1	
		5	

212. 9709_w19_MS_43 Q: 2

	Answer	Mark	Partial Marks
	PE gain $=150000g \times 500\sin\alpha$ $(=75000000g\sin\alpha)$	B1	Correct expression for PE gain
	$\frac{1}{2} \times 150000 \times 45^2 - \frac{1}{2} \times 150000 \times 42^2$ (=19575000)	B1	Correct expression for KE loss
		M1	For 5 term work energy equation (or 4 terms if using loss in KE as 1 term)
	$150000g \times 500\sin\alpha = 19575000 + 16000 \times 500 - 4 \times 10^6$	A1	
	$\alpha = 1.8$	A1	
		5	

213. 9709_w19_MS_43 Q: 5

	Answer	Mark	Partial Marks
(i)	Driving force $= \frac{240}{6}$ (= 40 N)	B1	Use of power = force × velocity
	$[40 - R = 80 \times 0.3]$	M1	Use of Newton's Second Law (3 terms)
	Resistance is 16 N	A1	AG
		3	
(ii)	$\left[\frac{240}{v} = 16\right]$	M1	Use of $P=Fv$ with DF=resistance
	Steady speed is 15 ms^{-1}	A1	
		2	
(iii)	Use of Newton's Second Law	M1	(4 terms)
	$\frac{240}{4} - 16 - 80g\sin 3 = 80a$	A1	
	Acceleration is 0.0266 ms^{-2}	A1	
		3	

214. 9709_m18_MS_42 Q: 3

	Answer	Mark	Partial Marks
(i)	$\frac{1}{2} \times 40 \times v^2 = 40 \times g \times 7.2$	M1	Use of KE gain = PE loss
	$v = 12\ \text{m s}^{-1}$	A1	
		2	
(ii)	Work done against friction(WDF) $\text{WDF} = 40 \times g \times 7.2 - \frac{1}{2} \times 40 \times 10^2\ [= 880]$	M1	May be calculated as $\frac{1}{2} \times 40 \times 12^2 - \frac{1}{2} \times 40 \times 10^2$
	$\frac{1}{2} \times 40 \times V^2 + 40 \times g \times 7.2 = \frac{1}{2} \times 40 \times 11^2 + 880$ **or** $\frac{1}{2} \times 40 \times V^2 = \frac{1}{2} \times 40 \times 11^2 - \frac{1}{2} \times 40 \times 10^2$	M1	For 4-term work-energy equation with numerical attempt at work done or using the fact that WDF is the same in both cases, extra initial KE = difference in final KEs
	$V = \sqrt{21} = 4.58$	A1	
		3	

215. 9709_m18_MS_42 Q: 6

	Answer	Mark	Partial Marks
(i)	Driving force = 35 × 60	M1	
	Power = $35 \times 60^2 = 126000$ W	A1	
		2	
(ii)	Driving force is $\text{DF} = \frac{126000}{30}$	B1FT	
	$\text{DF} - 35 \times 30 = 1200a$	M1	For 3-term Newton's 2nd law equation, dimensionally correct
	$a = \frac{3150}{1200} = \frac{21}{8} = 2.625\ \text{m s}^{-2}$	A1	AG
		3	
(iii)	$\text{DF} = \frac{126000}{v}$	M1	For $F = \frac{P}{v}$
	$\frac{126000}{v} = 35v + 1200g \times \frac{7}{48}$	M1	For 3-term force equation, or equivalent
		A1	For correct (unsimplified) equation
	$35v^2 + 1750v - 126000 = 0$ or $v^2 + 50v - 3600 = 0$	M1	For simplifying and solving of a 3-term quadratic attempted
	$v = 40\ \text{ms}^{-1}$	A1	$v = -90$ rejected or ignored
		5	

216. 9709_s18_MS_41 Q: 6

	Answer	Mark	Partial Marks
(i)	$[P = \text{DF} \times v = 850 \times 36]$	**M1**	Apply $P = \text{DF} \times v$ with DF = Resistance force
	Power = rate of working = 30.6 kW	**A1**	
		2	
(ii)	$[\text{DF} = 1250g \times 0.1 + 850]$	**M1**	Driving force comprising of resistance plus a weight component
	$\text{DF} = \dfrac{63000}{v}$	**M1**	$\text{DF} = \dfrac{P}{v}$
	$v = 30$ so speed of car is 30 ms^{-1}	**A1**	
		3	
(iii)	Gain in KE $= \dfrac{1}{2} \times 1250 \times (24^2 - 20^2)$	**B1**	[= 110 000]
	Loss in PE $= 1250g \times 176 \times 0.1$	**B1**	[= 220 000]
	WD by car's engine = 20 000 × 8	**B1**	[= 160 000]
	[160 000 + 220 000 = WD against resistance + 110 000]	**M1**	4 term work energy equation
	WD = 270 000 J = 270 kJ	**A1**	
		5	

217. 9709_s18_MS_41 Q: 7

	Answer	Mark	Partial Marks
(i)	A $T - 0.8\,g \sin 45 = 0.8a$ B $1.2g \sin 30 - T = 1.2a$ System $1.2\,g \sin 30 - 0.8\,g \sin 45 = 2a$	M1	Apply Newton 2nd law to either A or to B or to the system
		A1	One correct equation
		A1	A second correct equation
	$a = 0.171$	M1	Solve for a
	$v^2 = 2 \times a \times 0.4$	M1	Use $v^2 = u^2 + 2as$ with $u = 0$
	$v = 0.370$ so speed of A is $0.370\ \text{ms}^{-1}$	A1	
		6	
	Alternative scheme for Question 7(i)		
		M1	Attempt KE gain or PE loss
	KE gain $= \frac{1}{2} \times 0.8 \times v^2 + \frac{1}{2} \times 1.2 \times v^2$	A1	v is the required speed of A
	PE loss = $1.2\,g \times 0.4 \sin 30 - 0.8\,g \times 0.4 \sin 45$	A1	
	$\frac{1}{2} \times 0.8 \times v^2 + \frac{1}{2} \times 1.2 \times v^2 =$ $1.2\,g \times 0.4 \sin 30 - 0.8\,g \times 0.4 \sin 45$	M1	4 term energy equation
		M1	Solving for v
	$v = 0.370$ so speed of A is $0.370\ \text{ms}^{-1}$	A1	
(ii)	$R_A = 0.8g \cos 45 = 4\sqrt{2}$ $R_B = 1.2g \cos 30 = 6\sqrt{3}$	B1	For either R_A or R_B
	$F_A = 4\sqrt{2}\ \mu$ and $F_B = 6\sqrt{3}\ \mu$	M1	Either F_A or F_B used
	A $0.8\,g \sin 45 + F_A = T$ B $1.2\,g \sin 30 - F_B = T$ or system equation: $12 \sin 30 - 8 \sin 45 = F_A + F_B$	M1	Resolve parallel to the plane either for both particles A and B **or** for the system equation
	Correct equation(s)	A1	
		M1	Eliminate T and solve for μ
	$\mu = \frac{(6 - 4\sqrt{2})}{(6\sqrt{3} + 4\sqrt{2})}$ $= 0.0214$	A1	
		6	

218. 9709_s18_MS_42 Q: 1

	Answer	Mark	Partial Marks
	KE gain = $\frac{1}{2} \times 80 \times (5.5^2 - 4^2)$ [= 570]	**B1**	Either initial or final KE correct
	WD against Res = $60P$	**B1**	
	[$\frac{1}{2} \times 80 \times (5.5^2 - 4^2) + 60P = 1200$]	**M1**	Four term work-energy equation
	$P = 10.5$	**A1**	
		4	

219. 9709_s18_MS_42 Q: 2

	Answer	Mark	Partial Marks
	Driving force DF = $\frac{P}{15}$	**B1**	Correct use of $P = Fv$
	$\left[\text{DF} - 240\ 000g\sin 4 - 18\ 000 = 240\ 000 \times (-0.2)\right]$	**M1**	A four-term Newton 2nd law equation
		A1	Correct equation
	Power is 2 060 000 (W)	**A1**	Allow 2060 kW or 2.06 MW
		4	

220. 9709_s18_MS_43 Q: 4

	Answer	Mark	Partial Marks
	$[\frac{1}{2}\times 0.8\times v^2]$ or $[\frac{1}{2}\times 1.6\times v^2]$	M1	For KE of either particle
	Gain in KE $=\frac{1}{2}\times 0.8\times v^2+\frac{1}{2}\times 1.6\times v^2$	A1	Total KE
	[Gain in $PE_A = 0.8g\times 0.5\times\sin\theta$] or [Loss in $PE_B = 1.6g\times 0.5$]	M1	For PE change of either particle (irrespective of sign)
	Loss in PE $= 1.6g\times 0.5 - 0.8g\times 0.5\times 0.6$	A1	Change of PE
	$[1.2v^2 = 8 - 2.4]$	M1	Energy equation originating from 4 terms
	Speed is 2.16 (m s^{-1})	A1	
	Total:	6	
			SC for using Newton II equations and $v^2 = u^2 + 2as$ (**max 2/6**) $[16 - T = 1.6a$ and $T - 8\sin\theta = 0.8a] \rightarrow a = 4.67$ (ms^{-2}) **B1** $[v^2 = 2\times\frac{14}{3}\times 0.5] \rightarrow$ speed is 2.16 (ms^{-1}) **B1**
	Alternative method 1 for Question 4		
	$[\frac{1}{2}\times 0.8\times v^2]$ or $[0.8g\times 0.5\times\sin\theta]$	M1	For KE gain or PE gain of particle A
	$\frac{1}{2}\times 0.8\times v^2 + 0.8g\times 0.5\times 0.6$	A1	Total energy gain for particle A
	$[16 - T = 1.6a$ and $T - 8\sin\theta = 0.8a \rightarrow T = ...]$ 8.53	M1	Forms and solves Newton II equations to find tension T
	$WD_T = \frac{128}{15}\times 0.5$	A1	Finds $WD_{Tension}$
	$[\frac{1}{2}\times 0.8\times v^2 + 0.8g\times 0.5\times 0.6 = \frac{128}{15}\times 0.5]$	M1	Energy equation (3 terms)
	Speed is 2.16 (m s^{-1})	A1	
	Total:	6	
	Alternative method 2 for Question 4		
	$[\frac{1}{2}\times 1.6\times v^2]$ or $[1.6g\times 0.5]$	M1	For KE gain or PE loss of particle B
	$1.6g\times 0.5 - \frac{1}{2}\times 1.6\times v^2$	A1	Energy change for particle B
	$[16 - T = 1.6a$ and $T - 8\sin\theta = 0.8a \rightarrow T = ...]$ 8.53	M1	Forms and solves Newton II equations to find tension T
	$WD_T = \frac{128}{15}\times 0.5$	A1	Finds $WD_{Tension}$
	$1.6g\times 0.5 - \frac{1}{2}\times 1.6\times v^2 = \frac{128}{15}\times 0.5]$	M1	Energy equation (3 terms)
	Speed is 2.16 (m s^{-1})	A1	
	Total:	6	

221. 9709_s18_MS_43 Q: 6

	Answer	Mark	Partial Marks
(i)	$[\frac{P}{56} = 40 \times 56]$	M1	For equating $\frac{\text{Power}}{\text{Velocity}}$ to Resistance, or equivalent
	Power is 125 (kW)	A1	
	Total:	2	
(ii)	Driving force is $\frac{125\,440}{32}$	B1ft	Follow through their power from **(i)**
	$[\frac{125\,440}{32} - 40 \times 32 = 1400a]$	M1	For 3-term Newton II equation
	$a = 1.89\ (\text{m s}^{-2})$	A1	
	Total:	3	
(iii)	$[\frac{60\,000}{50} + 1400g\sin\theta - 40 \times 50 = 0]$	M1	For 3-term Newton II equation
		A1	Correct equation
	$[\sin\theta° = \frac{800}{14\,000}]$	M1	
	$\theta = 3.3$	A1	
	Total:	4	

222. 9709_w18_MS_41 Q: 2

	Answer	Mark	Partial Marks
(i)	Resistance = Driving force = $\frac{4080000}{85} = 48\,000$ N	B1	Correct use of $P = Fv$ and using DF = Resistance
		1	
(ii)	DF = $\frac{P}{85}$	B1	DF = $\frac{P}{v}$
	DF – 48 000 – 490 000 g × $\frac{1}{200}$ = 0	M1	For applying Newton's second law (3 terms)
	P = 72 500 × 85 = 6.16 MW	A1	
		3	

223. 9709_w18_MS_41 Q: 3

	Answer	Mark	Partial Marks
	[KE gained $= \frac{1}{2} \times 2500 \times (30^2 - 20^2)(= 625000\text{J})$ PE lost $= 2500g \times 400 \sin 4 (= 697564.7\text{J})$	**M1**	KE gained or PE lost attempted
		A1	Both KE and PE correct
	[WD by engine $+2500g \times 400 \sin 4 + \frac{1}{2} \times 2500 \times 20^2$ $= 600 \times 400 + \frac{1}{2} \times 2500 \times 30^2$]	**M1**	Using work-energy equation in the form WD by engine + PE lost = WD against F + KE gain
	Work done by engine + PE lost $= 600 \times 400 + 625\,000$	**A1**	Work-energy equation all correct
	Work done = 167 000 J (167 435.2…)	**A1**	
		5	

224. 9709_w18_MS_42 Q: 6

	Answer	Mark	Partial Marks
(i)	Power = 350 × 15 = 5250 W	**B1**	Allow 5.25 kW
		1	
(ii)		**B1**	Using Driving force DF = $P/15$
	DF + 1200g sin 1 – 350 = 1200 × 0.12	**M1**	For using Newton's 2nd law down the slope
	P = 4270 W (4268.56...)	**A1**	
		3	
(iii)	[1200g sin 1 – 350 = 1200a]	**M1**	Using Newton's 2nd law down the slope
		A1	Correct equation
	[$18^2 = 20^2 + 2as$]	**M1**	Using constant acceleration formulae with a complete method to find distance, s, travelled.
	Distance travelled s = 324 m (324.39)	**A1**	
(iii)	**Alternative method for Q6(iii)**		
	PE loss = 1200g × s sin 1 KE loss = ½ × 1200 × ($20^2 - 18^2$)	**M1**	Attempt either PE loss or KE loss
		A1	Both PE loss and KE loss correct
	[1200g × s sin 1 + ½ × 1200 × ($20^2 - 18^2$) = 350s]	**M1**	Apply work-energy equation to the car
	Distance travelled s = 324 m (324.39)	**A1**	
		4	

225. 9709_w18_MS_42 Q: 7

	Answer	Mark	Partial Marks
(i)	At liquid surface, speed = $0 + g \times 0.8$ [= 8] or $0.3g \times \frac{1}{2}(0 + v) \times 0.8 = \frac{1}{2}(0.3)v^2 \to v = 8$	B1	Using constant acceleration equation $v = u + at$ or PE loss = KE gain
	PE lost in water = $0.3g \times 1.25$ [= 3.75]	B1	
	[$\frac{1}{2} \times 0.3 \times (8^2 - v^2) + 0.3g \times 1.25 = 1.2$]	M1	Using work-energy for downward motion in the tank PE loss + KE loss = Work done against resistance
	$v = 9$ m s^{-1}	A1	
	Alternative method for Q7(i)		
	Height above tank = $\frac{1}{2} \times g \times 0.8^2$ [= 3.2]	B1	
	Total PE loss = $0.3g \times (3.2 + 1.25)$ [= 13.35]	B1	
	[$0.3g \times (3.2 + 1.25) = \frac{1}{2} \times 0.3 \times v^2 + 1.2$]	M1	Work-energy equation for the total downward motion
	$v = 9$ m s^{-1}	A1	
		4	
(ii)	[$-0.3g - 1.8 = 0.3a$]	M1	Using Newton's 2nd law for the upward motion in the tank
	$a = -16$	A1	
	[$1.25 = 7T + \frac{1}{2} \times (-16) \times T^2$]	M1	Using constant acceleration equations to find the time, T, for the particle to travel from the bottom to the surface of the liquid
	$T = 0.25$ (or 0.625, on the way down)	A1	
	[v at surface = $7 + (-16) \times 0.25 = 3$]	B1	Using $v = u + aT$ or equivalent to find v at surface
	[$0 = 3 - gt \to t = 0.3$]	M1	Attempt to find the time, t, taken for the particle to travel from the surface to reach maximum height using their $v \neq 7$
	Total time = $T + t = 0.55$ s	A1	
(ii)	**Alternative method for Q7(ii)**		
	[$-0.3g - 1.8 = 0.3a$]	M1	Using Newton's 2nd law for the upward motion in the tank
	$a = -16$	A1	
	$v^2 = 7^2 + 2 \times (-16) \times 1.25 = 9 \to v = 3$	B1	Using constant acceleration equations to find v at the surface
	$1.25 = \frac{1}{2}(7 + 3) \times T$ or $3 = 7 + (-16) \times T$	M1	Using $s = \frac{1}{2}(u + v) \times T$ or $v = u + aT$ to find the time, T, for the particle to travel from the bottom to the surface of the liquid
	$T = 0.25$	A1	
	[$0 = 3 - gt \to t = 0.3$]	M1	Attempt to find the time, t, taken for the particle to travel from the surface to reach maximum height using their $v \neq 7$
	Total time = $T + t = 0.55$ s	A1	

	Answer	Mark	Partial Marks
(ii)	**Second Alternative method for Q7(ii)**		
	$[\frac{1}{2} \times 0.3 \times (7^2 - v^2) = 0.3g \times 1.25 + 1.8 \times 1.25]$	M1	Work-energy equation for motion from bottom to surface
		A1	Correct equation
	$v = 3$	B1	Find v at surface from rearrangement of work-energy
	$[1.25 = \frac{1}{2}(7 + 3) \times T]$	M1	Using $s = \frac{1}{2}(u + v) \times T$ to find the time T, for the particle to travel from the bottom to the surface of the liquid
	$T = 0.25$	A1	
	$[0 = 3 - 10t \rightarrow t = 0.3]$	M1	Attempt to find the time, t, taken for the particle to travel from the surface to reach maximum height using their $v \neq 7$
	Total time $= T + t = 0.55$ s	A1	
		7	

226. 9709_w18_MS_43 Q: 3

	Answer	Mark	Partial Marks
(i)	$[\frac{1}{2} \times 1.2 \times 7.5^2 - \frac{1}{2} \times 1.2 \times v^2 = 25]$	M1	For use of KE and 25 in a 3 term equation
	$v = 3.82$ m s^{-1} (3.81881…)	A1	
		[2]	
(ii)	$1.2gd\sin 30$	B1	Correct expression for PE
	$[\frac{1}{2} \times 1.2 \times 7.5^2 - 25 + 1.2gd\sin 30 = \frac{1}{2} \times 1.2 \times 9^2]$	M1	For 4 term work / energy equation
	$d = 6.64$ m (6.64166…)	A1	
		3	

227. 9709_w18_MS_43 Q: 6

	Answer	Mark	Partial Marks
(i)	Driving force = 36000 / 20	B1	For use of power = Fv
	[36000 / 20 – R = 3200 × 0.2]	M1	Use of Newton's Second Law
	R = 1160 N	A1	
		[3]	
(ii)	Driving force F = 3200gsin1.5 + 1160	M1	Resolving along plane
	[Power = (3200gsin1.5 + 1160) × 30]	M1	Use of $P = Fv$
	Power = 59900 W (59929.87…)	A1	
		3	
(iii)	[– (3200gsin1.5 + 1160) = 3200a]	M1	Use of Newton's Second Law
	(a = –0.62426…)	A1	
	[$0^2 = 30^2 + 2as$]	M1	Use of $v^2 = u^2 + 2as$ to find s
	Distance s = 721 m (720.84…)	A1	
		4	
	OR:		
(iii)	[3200gsin1.5s] or [½ × 3200 × 900]	M1	For PE gain or KE loss
	3200gsin1.5s and ½ × 3200 × 900	A1	For PE gain and KE loss
	[½ × 3200 × 900 = 1160s + 3200gsin1.5s]	M1	For work / energy equation
	Distance s = 721 m (720.84…)	A1	
		4	

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228. 9709_m17_MS_42 Q: 1

	Answer	Mark	Partial Marks
(i)	KE = ½ × 0.4 × 12^2 = 28.8 J	B1	
	Total:	1	
(ii)	PE gain = 0.4gh [= 4d sin 30]	B1	h = height gained d = distance travelled up the plane
	4h = 28.8	M1	Using KE loss = PE gain
	h = 7.2 h = d sin 30 d = 14.4 m	A1	
	Total:	3	

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229. 9709_m17_MS_42 Q: 4

	Answer	Mark	Partial Marks
(i)	$36000 = 800v$	M1	Using $P = Fv$
	$v = 45\,\mathrm{m\,s^{-1}}$	A1	Speed of the car
	$AB = 45 \times 120 = 5400\,\mathrm{m}$	A1	
	Total:	**3**	
(ii)	$-800 = 900a$ $[a = -8/9]$	M1	Using Newton's 2nd law
	$v^2 = 45^2 - \frac{16}{9} \times 450$	M1	Using $v^2 = u^2 + 2as$
	$v = 35\ \mathrm{m s^{-1}}$	A1	Speed of the car at C
	Total:	**3**	
	Alternative method for Question 4(ii)		
	$0.5 \times 900 \times (45 - v^2)$	M1	Attempt change in KE
	$0.5 \times 900 \times (45 - v^2) = 800 \times 450$	M1	KE loss = WD against Friction
	$v = 35\ \mathrm{m s^{-1}}$	A1	Speed of the car at C
	Total:	**3**	
(iii)	$CD = 6637.5 - 5400 - 450 = 787.5$	B1	
	$0 = 35^2 - 2d \times 787.5$	M1	Using $v^2 = u^2 + 2as$, $a = -d$
	$d = 7/9 = 0.778\,\mathrm{m\,s^{-2}}$	A1	d = deceleration
	$P = 900 \times (7/9) = 700$	A1	Using $F = ma$
	Total:	**4**	

230. 9709_s17_MS_41 Q: 1

	Answer	Mark	Partial Marks
	PE loss = $0.6 \times 10 \times 8$ [= 48]	B1	
	KE gain = ½ (0.6) 10^2 [= 30]	B1	
	WD against Res = 48 – 30 = 18 J	B1	
	Total:	**3**	

231. 9709_s17_MS_41 Q: 4

	Answer	Mark	Partial Marks
(i)		M1	Attempt KE and/or PE with correct dimensions
	KE gain = ½ × 800 × (14^2 – 8^2) = 52800 J	A1	
	PE gain = 800 × 10 × 120 × 0.15 = 144000 J	A1	
	Total:	3	
(ii)	WD by engine = 32000 × 12	B1	
	32000 × 12 = 144000 + 52800 + WD against F	M1	Work/Energy equation 4 terms
	WD against F = 187200 J	A1	WD = 187000 to 3sf
	Total:	3	

232. 9709_s17_MS_42 Q: 1

	Answer	Mark	Partial Marks
	EITHER: WD = 20 cos θ × 1.5 × 12 (J)	(B1	Using WD = $Fd\cos\theta$
	[cos θ = 50/360] θ = ...	M1	Use WD = 50 and solve for θ
	$\theta = 82(.0)$	A1)	
	OR: Power P = 50/12 = 4.1666…	(B1	Using Power = WD/time
	[50/12 = 20 cos θ × 1.5] θ = ...	M1	Use $P = Fv$ and solve for θ
	$\theta = 82(.0)$	A1)	
	Total:	3	

233. 9709_s17_MS_42 Q: 2

	Answer	Mark	Partial Marks
(i)	$v = \sqrt{2\times2.5\times5}$ (ms^{-1})	B1	**AG** Using $v^2 = u^2 + 2as$
	Total:	1	
(ii)(a)		M1	Attempting PE loss or KE gain
	PE loss = 0.2 × 10 × 6 sin 30 [= 6] **and** KE gain = 0.5 × 0.2 × (v^2 – 5^2)	A1	Both PE **and** KE correct both unsimplified
	[6 = 0.1(v^2 – 5^2)]	M1	PE loss = KE gain (3 terms)
	$v^2 = 85 \rightarrow v = 9.22$ ms^{-1}	A1	
	Total:	4	
(ii)(b)	Max velocity at lowest point [0.2 × 10 × 6 = 0.5 × 0.2 × (v^2 – 5^2)]	M1	PE loss = KE gain
	$v^2 = 145 \rightarrow v = 12(.0)$ ms^{-1}	A1	
	Total:	2	

234. 9709_s17_MS_42 Q: 4

	Answer	Mark	Partial Marks
(i)(a)	$[P = 850 \times 42]$	M1	Using $P = Fv$
	$P = 35700$ W = 35.7 kW	A1	Must be in kW to 3sf
	Total:	2	
(i)(b)	$P = 41700$ $\rightarrow$ [DF = 41700/42]	M1	Find new power and new DF based on power found in 4(i)(a)
	$[(993 - 850) = 1200a]$	M1	Apply Newton 2, three terms
	$a = 5/42 = 0.119$ ms^{-2}	A1	
	Total:	3	
(ii)	DF = 80000/24	B1	DF = P/v
	[DF – 850 – mg sin θ = 0]	M1	Newton 2 along the hill, 3 terms
	[12000 sin θ = 80000/24 – 850] θ = …..	M1	Solve for θ, from a three term equation
	θ = 11.9	A1	
	Total:	4	

235. 9709_s17_MS_42 Q: 6

	Answer	Mark	Partial Marks
(i)	A [$T = 0.3a$] B [$1.5g\sin\theta - T = 1.5a$] System [$1.5g\sin\theta = 1.8a$]	M1	Apply Newton's second law to A or to B or to the system
		A1	Any two correct equations
		M1	Solve 2 simultaneous equations for a and/or T or use the system equation.
	$a = 9/1.8 = 5\ \text{ms}^{-2}$	A1	
	$T = 1.5$ N	A1	
	Total:	**5**	
(ii)	[$5 = 3a$]	M1	$v = u + at$ used with $t = 3$, $u = 0$, $v = 5$
	$a = 5/3 = 1.67$	A1	
	$R_A = 3$ $R_B = 15\cos 36.9 = 12$	B1	For either reaction
	[$F_A = 3\mu$ $F_B = 12\mu$]	M1	Use $F = \mu R$ for either term
	EITHER: A [$T - F_A = 0.3a$] B [$15\sin 36.9 - T - F_B = 1.5a$] System equation is [$1.5g\sin 36.9 - F_A - F_B = 1.8a$]	(M1	Apply Newton's second law to A or to B or to the system
		A2/1/0	**A1** Correct equation for A or B **A2** Correct equations for A and B OR **A2** Correct system equation
	[$9 - 15\mu = 3$]	M1	Solve for μ from equations with correct number of terms
	$\mu = 0.4 = 2/5$	A1)	
	OR: $s = ½\,(5/3) \times 3^2 = 7.5$	(B1	Find distance travelled in 3 secs
	PE loss = $1.5 \times 10 \times 7.5 \times (3/5) = 67.5$	B1	
	KE gain = $½\,(1.8) \times 5^2 = 22.5$	B1	
	[$67.5 = 22.5 + 3\mu \times 7.5 + 12\mu \times 7.5$]	M1	Use Work/Energy equation
	$\mu = 2/5 = 0.4$	A1)	
	Total:	**9**	

236. 9709_s17_MS_43 Q: 1

	Answer	Mark	Partial Marks
(i)	WD = 35 cos 20 × 12	M1	Uses WD = $Fd\cos\theta$
	395 J	A1	
	Total:	2	
(ii)	*EITHER:* WD against resistance = 15 × 12	(B1	
	35cos20 × 12 = 15 × 12 + ½ $(25v^2)$	M1	Uses $WD_{man} = WD_{resistance}$ + KE gain
	$v = 4.14$ ms^{-1}	A1)	
	OR: 35 cos 20 – 15 = 25 a [$a = 0.716$]	(B1	Applies Newton's Second Law
	$v^2 = 2 \times 0.7155. \times 12$	M1	Uses $v^2 = u^2 + 2as$
	$v = 4.14$ ms^{-1}	A1)	
	Total:	3	

237. 9709_s17_MS_43 Q: 6

	Answer	Mark	Partial Marks
(i)(a)	16 000 = $F \times 40$	M1	Using $P = Fv$
	Resistance is 400 N	A1	
	Total:	2	
(i)(b)	22 500 = $F \times 45$ $F = 500$	B1	
	500 – 400 = 1200a	M1	Applying Newton's Second Law
	$a = \dfrac{1}{12} = 0.0833$ (ms^{-2})	A1	
	Total:	3	
(ii)	16 000 = $(590 + 2v)v$	M1	Using $P = Fv$
	$[2v^2 + 590v - 16\,000 = 0] \to v = \ldots$	M1	Solving for v
	$v = 25$ (ms^{-1})	A1	
	Total:	3	

238. 9709_w17_MS_41 Q: 2

	Answer	Mark	Partial Marks
(i)	Power = 1150 × 12 = 13 800W	**B1**	For use of $P = F \times v$ Allow 13.8 kW
		1	
(ii)	Driving force = $\frac{25000}{12}$	**B1**	Using $F = \frac{P}{v}$
	$\frac{25000}{12} - 1150 - 3700g \sin 4 = 3700a$	**M1**	For applying Newton's 2nd law up the slope, 4 terms
	$a = -0.445 \text{ m s}^{-2}$	**A1**	
		3	
(iii)	$\frac{25000}{v} - 1150 - 3700g\sin 4 = 0$	**M1**	For stating the equation for constant v, with 3 terms, and solving for v
	$v = 6.70 \text{ m s}^{-1}$	**A1**	
		2	

239. 9709_w17_MS_41 Q: 3

	Answer	Mark	Partial Marks
(i)	640 × 18	**M1**	For use of work done = $F \times d$
	Work done = 11 520 J	**A1**	
		2	
(ii)	KE at start = ½ × 840 × 14^2 = 82 320 J	**B1**	
	PE gained = 840g × 8sin 30 – 840g × 10sin 20 = 4870 J	**B1**	
	½ × 840 × v^2 = 82 320 – 11 520 – 4870	**M1**	For using work – energy equation with 4 terms and solving for v
	$v = 12.5 \text{ m s}^{-1}$	**A1**	
		4	

240. 9709_w17_MS_42 Q: 5

	Answer	Mark	Partial Marks
(i)	*EITHER:* Resistance force = $\frac{600}{25}$ = 24 N	(B1	
	Weight component = 80 g (0.04) = 32 N	B1	For correct unsimplified numerical form of the weight component
	[Power = 56 × 4]	M1	For use of $P = Fv$ where F is from two relevant force terms
	Power = 224 W	A1)	
		4	
	OR: PE gain = 80g × 25 (0.04) = 800	(B1	For a correct unsimplified numerical expression for PE
	Time taken = $\frac{25}{4}$ = 6.25	B1	
	[WD by cyclist = P × 6.25 = 800 + 600]	M1	For using WD = $P \times t$ where WD is from two relevant terms
	Power = 224 W	A1)	
		4	
(ii)	Work done by cyclist = 224 × 10 (= 2240J)	B1 FT	For stating WD = power × time FT on P value found in **5(i)**
	Initial KE = ½ × 80 × 4^2 [= 640 J]	B1	
	[½ × 80v^2 = 640 + P×10 – 1200]	M1	For using Work/Energy equation
	Speed = 6.48 m s^{-1}	A1	Allow speed = √42
		4	

241. 9709_w17_MS_43 Q: 2

	Answer	Mark	Partial Marks
(i)	[$F = 1480 + 7850g \sin 3$] (= 5588)	**M1**	
	[$\frac{P}{10} = 1480 + 7850g \sin 3$] $\rightarrow P = \ldots$	**M1**	Using $P = Fv$ and solving for P
	Power = 55 900 W	**A1**	
		3	
(ii)	[$F + 7850g \sin 3 - 1480 = 7850 \times 0.8$] ($F = 3652$)	**M1**	Use of Newton's Second Law
	[$\frac{P}{15} + 7850g \sin 3 - 1480 = 7850 \times 0.8$] $\rightarrow P = \ldots$	**M1**	Using $P = Fv$ and solving for P
	Power = 54800 W	**A1**	
		3	

242. 9709_w17_MS_43 Q: 4

	Answer	Mark	Partial Marks
(i)	*EITHER:* $[T - 0.35g = 0.35a$ or $0.45g - T = 0.45a$ or $0.45g - 0.35g = 0.8a]$	(M1	Applies Newton's Second Law to one of the particles or forms system equation in a $(m_Bg - m_Ag = (m_A + m_B)a)$
	$[0.45g - T = 0.45a$ or $T - 0.35g = 0.35a] \rightarrow a = \ldots$	M1	Applies Newton's Second Law to form second equation in T and a and solves for a or solves system equation for a
	$a = 1.25$ m s^{-2}	A1	
	$[v^2 = 2 \times 1.25 \times 0.64]$ $(= 1.6)$	M1	Using $v^2 = u^2 + 2as$
	Velocity = 1.26 ms^{-1}	A1)	
	OR: [PE loss = $0.45g \times 0.64 - 0.35g \times 0.64$]	(M1	Attempts PE loss
	[KE gain = ½ $(0.35 + 0.45)$ v^2]	M1	Attempts KE gain
	PE loss = $0.45g \times 0.64 - 0.35g \times 0.64$ and KE gain = ½ $(0.35 + 0.45)$ v^2	A1	
	[½ (0.8) $v^2 = 0.1g \times 0.64$] $(v^2 = 1.6)$	M1	Using PE loss = KE gain
	Velocity = 1.26 ms^{-1}	A1)	
		5	
(ii)	*EITHER:* $[0 = 1.6 - 2\ gs]$ $(s = 0.08)$	(M1	Using $v^2 = u^2 + 2as$
	Distance = 0.16 m	A1)	
	OR: $[0.35gh = ½\ (0.35) \times 1.6]$ $(h = 0.08)$	(M1	Using PE gain = KE loss for particle A
	Distance = 0.16 m	A1)	
		2	

243. 9709_w17_MS_43 Q: 7

	Answer	Mark	Partial Marks
(i)	$R = 0.2g\cos 30 - T\sin 15$	B1	
	$[F = 0.3 \times (0.2g\cos 30 - T\sin 15)]$	M1	Use of $F = \mu R$
		M1	For resolving along the plane
	$T\cos 15 + 0.3 \times (0.2g\cos 30 - T\sin 15) = 0.2g\sin 30$	A1	
		M1	For solving a 4 term equation for T
	$T = 0.541$	A1	
		6	
(ii)	$0.3 \times 0.2g\cos 30 \times 3$ [= 1.5588 J]	B1	WD against F = friction × distance
	WD = 0.25 × 3 [= 0.75 J]	B1	WD against 0.25 force
	$0.2g \times 3\sin 30$ [= 3 J]	B1	PE loss = mgh
	$[\frac{1}{2}(0.2)v^2 = 3 - 1.5588 - 0.75]$	M1	Work/Energy equation
	Speed = 2.63 ms^{-1}	A1	
		5	

244. 9709_m16_MS_42 Q: 1

	Answer	Mark		Partial Marks
		M1		Attempt KE gain **or** WD against Res
	KE gain = $\frac{1}{2} \times 105 \times (10^2 - 5^2)$ WD against Resistance = 50 × 40	A1		Both correct (unsimplified) KE gain = 3937.5 J WD = 2000 J
	Total WD = 5937.5 J	B1	3	WD = KE gain + WD against Res
	Alternative method			
	$10^2 = 5^2 + 2 \times 50 \times a$ [$a = 0.75$] DF – 40 = 105a	M1		Using $v^2 = u^2 + 2as$ and applying Newton's 2nd law to the system
	DF = 40 + 105 × 0.75 = 118.75	A1		
	Total WD = 118.75 × 50 = 5937.5 J	B1	3	WD = DF × 50

245. 9709_m16_MS_42 Q: 2

	Answer	Mark		Partial Marks
(i)	DF = 1350	**B1**		
	$P = 1350 \times 32 = 43.2$ kW	**B1**	2	
(ii)	DF – 1350 – 1200g × 0.1 = 0 [DF = 2550]	**M1**		For using Newton's 2nd law applied to the car up the hill (3 terms) Allow use of $\theta = 5.7^\circ$
	DF = 76500/v	**M1**		For using DF = P/v
	$v = 30\,\text{ms}^{-1}$	**A1**	3	

246. 9709_m16_MS_42 Q: 5

	Answer	Mark		Partial Marks
(i)	[2500 – 2000g × 0.1 – 250 = 2000a]	**M1**		For using Newton's 2nd law for the system or for applying Newton's 2nd law to the car and to the trailer and for solving for a Allow use of $\alpha = 5.7^\circ$ throughout
	$a = 1/8 = 0.125\,\text{ms}^{-2}$	**A1**		
	2500 – T – 100 – 1200g × 0.1 = 1200 × 0.125 or T – 150 – 800g × 0.1 = 800 × 0.125	**M1**		For applying Newton's 2nd law either to the car or to the trailer to set up an equation for T
	T = 1050 N	**A1**	4	
(ii)	–2000g × 0.1 – 250 = 2000a [a = – 1.125]	**M1**		For applying Newton's 2nd law to the system with no driving force to set up an equation for a
	0 = 30 – 1.125t	**M1**		For using $v = u + at$
	t = 26.7 s	**A1**	3	Allow t = 80/3 s
	Alternative method for 5(ii)			
(ii)	[½ (2000) 30^2 = 250s + 2000 × g × 0.1s] → s = 400	**M1**		Apply work/energy equation to find s the distance travelled up the plane with no driving force (3 terms) as: KE loss = WD against F + PE gain
	[400 = ½ (30 + 0)t]	**M1**		For using x = ½(u + v)t
	t = 26.7 s	**A1**	3	Allow t = 80/3 s

247. 9709_s16_MS_41 Q: 2

	Answer	Mark		Partial Marks
(i)	WD = 40 × 36 = 1440 J	**B1**	[1]	
(ii)		**M1**		Using PE = mgh
	PE = 25 × g × 36 sin 20 = 3080 J	**A1**	[2]	[PE = 3078.18]
(iii)	WD by pulling force = **(i)** + **(ii)**	**M1**		For using WD by pulling force = Gain in PE + WD against F
	WD = 4520 J	**A1**	[2]	[WD = 4518.18]
Alternative for (iii)				
(iii)	[(25g sin 20+ 40) × 36]	**M1**		For attempting to find the pulling force and multiply it by 36 to find the work done
	WD = 4520 J	**A1**	[2]	[WD = 4518.18]

248. 9709_s16_MS_41 Q: 3

	Answer	Mark		Partial Marks
(i)	Driving Force = 300	**B1**		Using DF = Resistance
	P = 300 × 40	**M1**		Using $P = Fv$
	P = 12000 W = 12 kW	**A1**	[3]	Must give answer in kW
(ii)	P = 0.9 × 12000 = 10800	**B1√**		ft on 12000
	$\frac{10\,800}{25} - 300 = 1000a$	**M1**		Applying Newton's second law with 3 terms to the car
	a = 132/1000 = 0.132 ms^{-2}	**A1**	[3]	

249. 9709_s16_MS_41 Q: 7

	Answer	Mark		Partial Marks
(i) (a)	$200 - 30g \sin 20 = 30a$	M1		For applying Newton's second law with 3 terms parallel to the plane
	$a = 3.25\ \text{ms}^{-2}$	A1	[2]	[$a = 3.2465$]
(b)	[$v^2 = 2 \times 3.2465 \times 12 = 77.9$]	M1		For using $v^2 = u^2 + 2as$ and attempting to find KE change
	KE change $= 0.5 \times 30 \times 77.9 = 1170$ J	A1	[2]	[KE = 1168.7 J]
	Alternative method for 7(i)(b)			
(b)	KE change = $200 \times 12 - 30g \times 12 \sin 20$	M1		Using KE gain = WD by DF – PE gain
	KE change = 1170 J	A1	[2]	
(ii) (a)	$N = 30g \cos 20$	B1		[$N = 281.9$]
	$F = 0.12 \times 30g \cos 20$ [= 33.8]	M1		Using $F = \mu Na$
	$200 - 30g \sin 20 - 33.8 = 30a$	M1		For using Newton's second law with 4 terms applied to the particle
	$a = 2.12\ \text{ms}^{-2}$	A1	[4]	
(b)	$N + 200 \sin 10 = 30g \cos 20$ [$N = 247.2$]	M1		For resolving forces perpendicular to the plane. Three term equation.
	$F = 0.12\ N$ [$= 0.12 \times 247.2 = 29.66$]	M1		N must be from a 3 term equation
	$200 \cos 10 - 29.66 - 30g \sin 20 = 30a$	M1		For using Newton's second law with 4 terms applied to the particle
	$a = 2.16\ \text{ms}^{-2}$	A1	[4]	

250. 9709_s16_MS_42 Q: 3

	Answer	Mark		Partial Marks
(i)	[80x sin 22.6 or 80x(5/13)]	**M1**		For using PE change = mgh PE change = 8 × g × x sin α
	$=\frac{400}{13}x = 30.8x$	**A1**	2	Allow α = 22.6 used
(ii)	WD against friction = 15 × x	**B1**		
	$\frac{1}{2}\times 8\times 5^2$	**B1**		
	$\frac{1}{2}\times 8\times 5^2 = \frac{400}{13}x + 15x$	**M1**		For using KE loss = PE gain + WD against friction
	$x = \frac{260}{119} = 2.18$	**A1**	4	

251. 9709_s16_MS_42 Q: 6

	Answer	Mark		Partial Marks
(i) (a)	Power = 1550 × 40 W	**M1**		Using Power = Fv where F = Resistance force
	Power = 62000 W = 62 kW	**A1**	2	Answer must be in kW
(b)	(62000 – 22000) = DF × 40 [DF = 1000]	**B1ft**		For stating P – 22000 = DF × 40 to find the new driving force. ft on Power found in **(i)(a)**
	DF – 1550 = 1100a	**M1**		For applying Newton's second law to the car (3 terms)
	$a = -0.5$ ms^{-2} or $d = 0.5$ ms^{-2}	**A1**	3	
(ii)	DF = 1100g sin 8 + 1550 [= 3081]	**M1**		For stating the equilibrium of the three forces
	80000 = 3081v	**M1**		For using $P = Fv$ with F involving a weight and a resistance term
	v = 26(.0) ms^{-1}	**A1**	3	

252. 9709_s16_MS_43 Q: 1

	Answer	Mark		Partial Marks
(i)	[PE gain = $8g \times 20\sin30^\circ$]	**M1**		For using PE gain = mgh
	Change in PE is 800 J	**A1**	2	
(ii)	[$8g$ x $20\sin30^\circ + 20F = 1146$]	**M1**		For using PE gain + WD against friction = 1146
	Frictional force is 17.3 N	**A1**	2	

253. 9709_s16_MS_43 Q: 5

	Answer	Mark		Partial Marks
(i)	[$20000/v = 650$]	**M1**		For using DF = P/v and for resolving forces along the direction of motion
	Speed is 30.8 ms^{-1}	**A1**	2	
(ii)	[DF = $650 + 1400g \times {}^1/_7$]	**M1**		For resolving forces along the direction of motion
	$P/10 = 650 + 1400g \times {}^1/_7$	**M1**		For using DF = P/v
	Power is 26500 W	**A1**	3	
(iii)	$P = 0.8 \times 26500(21200)$	**B1**√		ft $0.8 \times P$ from (ii)
	[$21200/20 + 1400g \times {}^1/_7 - 650 = 1400a$]	**M1**		For using Newton's Second Law
	Acceleration is 1.72 ms^{-2}	**A1**	3	

254. 9709_s16_MS_43 Q: 6

	Answer	Mark		Partial Marks
(i) (a)		**M1**		For applying Newton's Second Law to one particle or for using $m_1g - m_2g = (m_1 + m_2)a$
	$1.3g - T = 1.3a$ and $T - 0.7g = 0.7a$ or $1.3g - 0.7g = (1.3 + 0.7)a$ and either $1.3g - T = 1.3a$ or $T - 0.7g = 0.7a$	**A1**		
	Tension is 9.1 N	**B1**		
(b)	Acceleration is 3 ms^{-2}	**B1**		
	$[2 = ½ \times 3 \times t^2]$	**M1**		For using $s = ½ at^2$
	Time taken is 1.15 seconds	**A1**	6	
(ii)	$[v^2 = 2 \times 3 \times 2]$	**M1**		For using $v^2 = u^2 + 2as$ to find the speed on reaching plane
	$v = \sqrt{12}(3.464)$	**A1**√		ft√(4a)orat from (i)
	$[0 = 12 - 2gs \rightarrow s = ...]$	**M1**		For using $v^2 = u^2 + 2as$ to find the distance 0.7 kg particle continues upwards
	Greatest height is 4.6 m	**A1**	4	
	Alternative			
(ii)	$[1.3g \times 2 = ½ (1.3)v^2 + 9.1 \times 2]$ or $[9.1 \times 2 = ½ (0.7)v^2 + 0.7g \times 2]$	**M1**		For using PE loss = KE gain + WD_T for 1.3 kg or for using WD_T = KE gain + PE gain for 0.7 kg
	$v = \sqrt{12}(3.464)$	**A1**√		ft√(4a) or at from (i)
	$[½ \times 0.7v^2 = 0.7gs \rightarrow s = ...]$	**M1**		For using KE loss = PE gain
	Greatest height is 4.6 m	**A1**	4	

255. 9709_w16_MS_41 Q: 5

	Answer	Mark		Partial Marks
(i)	$a = 0.5\,\mathrm{m\,s^{-2}}$	**B1**	[1]	
(ii)	[Distance $= 25 + 100 + 5(5 + V) + 30V + 10V$]	**M1**		For attempting to find the distance travelled
	$150 + 45V$ AG	**A1**		
	$150 + 45V = 465 \rightarrow V = 7\,\mathrm{m\,s^{-1}}$	**B1**	[3]	
(iii)	$\frac{1}{2} \times 80 \times 7^2 - \frac{1}{2} \times 80 \times 5^2$ [= 960]	**M1**		For change in KE
	$20 \times (5 + 7)/2 \times 10$ [=1200]	**M1**		For work done against friction using $F \times d$
	[$80gh = 960 + 1200$]	**M1**		For using PE loss = KE gain + WD against Res.
	$h = 2.7\,\mathrm{m}$	**A1**	[4]	

256. 9709_w16_MS_41 Q: 6

	Answer	Mark		Partial Marks
(i)	[Work done = 50 cos10 × 20]	M1		Using WD = $Fd\cos\theta$
	= 984.8 J	A1	[2]	
(ii)	[984.8 = ½ × 25v^2 + 30 × 20]	M1		Using WD by DF = KE gain + WD against Res.
	v = 5.55 m s^{-1}	A1	[2]	
(iii)		M1		For using Power = Fv
	Max power = 50cos10 × 5.55 = 273 W	A1	[2]	Greatest power is at v_{max}
(iv)	[50 cos10 – 30 – 25g sin5 = 25a]	M1		For using Newton's 2nd law up the plane
	a = – 0.102 m s^{-2}	A1		
	[0 = 5.55 – 0.102t]	M1		For using $v = u + at$
	Time t = 54.4 s	A1	[4]	
	Alternative for 6(iv)			
		M1		For using WD by DF + KE loss = PE gain + WD against Res to find distance s up plane
	50 cos 10 × s + ½ × 25 × 5.55^2 = 25g × s sin 5 + 30 × s	A1		s = 151 m
		M1		For using s = ½($u + v$)t
	t = 302/5.55 = 54.4 s	A1	[4]	

257. 9709_w16_MS_42 Q: 4

	Answer	Mark		Partial Marks
(i)	PE loss = $mg \times 100\sin 20$	**B1**		
	$[\frac{1}{2}mv^2 - \frac{1}{2}m \times 5^2 = mg \times 100\sin 20]$	**M1**		Using KE gain = PE loss
	$v = 26.6\,\text{ms}^{-1}$	**A1**	[3]	
	Alternative method for 4(i)			
	$a = g\sin 20\ [= 3.42]$	**B1**		
	$[v^2 = 5^2 + 2 \times a \times 100]$	**M1**		Using $v^2 = u^2 + 2as$
	$v = 26.6\,\text{ms}^{-1}$	**A1**	[3]	
(ii)	KE = $\pm(0.5m \times 441 - 0.5m \times 25)\ [= \pm 208m]$	**B1**		
	$[mg \times 100\sin 20 = 8500 + 208m]$	**M1**		For using PE loss = WD against Friction + KE gain
	Mass $m = 63.4\,\text{kg}$	**A1**	[3]	

258. 9709_w16_MS_42 Q: 6

	Answer	Mark		Partial Marks
(i)	[Power = 400 × 25]	**M1**		For using $P = Fv$ where $F =$ resistance = 400 N
	Power = 10000 W	**A1**	[2]	Allow 10 kW
(ii)	Tension = 100 N	**B1**	[1]	Considering the trailer
(iii)	New driving force = 25000 / 20 = 1250 N	**B1**		Driving force = P/v at the instant when $v = 20$
	$[\text{DF} - 300 - T - 3000g\sin 4 = 3000a]$ or $[T - 100 - 500g\sin 4 = 500a]$ or $[\text{DF} - 400 - 3500g\sin 4 = 3500a]$	**M1**		For using Newton's second law applied **either** to the van **or** to the trailer **or** to the system of van and trailer.
		M1		For using N2 applied to one of the other cases
	$[a = -0.4547$ may be seen$]$	**M1**		Solving or using substitution to find T
	$T = 221\,\text{N}$	**A1**	[5]	Allow $T = 1550/7\,\text{N}$

259. 9709_w16_MS_43 Q: 1

	Answer	Mark		Partial Marks
(i)	PE gain = $50g \times 3.5$ (=1750)	**B1**		
	[WD = $50g \times 3.5 + 25 \times 3.5$]	**M1**		For using WD = PE gain + WD against resistance
	Work done = 1837.5 J or 1840 J	**A1**	[3]	
(ii)	[P = 1837.5/2] or [$P/v = 50g + 25$ **and** 3.5=2v]	**M1**		For using P = WD/t or for using $P = Fv$ **and** $s = vt$
	Power = 919 W	**A1**	[2]	

260. 9709_w16_MS_43 Q: 6

	Answer	Mark		Partial Marks
(i)	Driving force = 160/5 (= 32 N)	**B1**		
	[160/5 – 20 = $m \times 0.15$]	**M1**		For using Newton's Second Law
	Total mass is 80 kg AG	**A1**	[3]	
(ii)	[$300/v - 20 - 80g\sin 2° = 0$]	**M1**		For resolving up hill
	Speed is 6.26 ms^{-1} AG	**A1**	[2]	
(iii)	Driving force = 300/(0.9 × 6.26) (= 53.2 N)	**B1**		
		M1		For using Newton's Second Law
	$300/(0.9 \times 6.26) - 20 - 80g\sin 2° = 80a$	**A1**		
	Acceleration is 0.0666 ms^{-2}	**A1**	[4]	

261. 9709_w16_MS_43 Q: 7

	Answer	Mark		Partial Marks
(i)	$R = 50g\cos 10°$ and $F = 50g\sin 10°$	**B1**		
	$\mu \geqslant 0.176$	**B1**	[2]	$\mu \geqslant F \div R$ Allow $\mu \geqslant \tan 10°$
(ii)	PE loss = $50g \times d\sin 10°$	**B1**		$d = 5$ or $d = 10$
	WD against friction = $0.19 \times 50g\cos 10° \times d$	**B1**		$d = 5$ or $d = 10$
		M1		For using WD by 50 N force + PE loss – WD against friction = KE gain
	$50 \times 5 + 50g \times 10\sin 10° - 0.19 \times 50g\cos 10° \times 10 = 0.5 \times 50v^2$	**A1**		
	Speed is $2.70\,\text{ms}^{-1}$	**A1**	[5]	
				SC for candidates using Newton's Second law: max 2/5 B1 $v = 2.94\,\text{ms}^{-1}$ after 5 m B1 Speed is $2.70\,\text{ms}^{-1}$
(iii)	$50g\sin 20° -$ $0.19 \times 50g\cos 20° = 50a$	**M1**		For using Newton's Second Law
	Acceleration is $1.63\,\text{ms}^{-2}$	**A1**	[2]	

262. 9709_s15_MS_41 Q: 1

	Answer	Mark		Partial Marks
(i)	$[20 + 25\sin\theta = 2.7g]$	M1		For resolving forces vertically
	$\sin\theta = 0.28$	A1	2	**AG**
(ii)	$[25 \times 5 \times \sqrt{(1 - 0.28^2)}]$	M1		For using WD = $Fd\cos\theta$
	Work done is 120 J	A1	2	

263. 9709_s15_MS_41 Q: 4

	Answer	Mark		Partial Marks
(i)		M1		For using KE gain = $\frac{1}{2}mv_B^2$ or PE loss = $mg \times AB\sin\theta$
	For KE gain = 4032×10^3 or PE loss = $42 \times 10^6\sin\theta$	A1		
	PE loss = $42 \times 10^6\sin\theta$ or KE gain = 4032×10^3	B1	3	
(ii)		M1		For using WD by DF = KE gain – PE loss + WD by resistance
	$5000 = 4032 - 42000\sin\theta + 3360$	A1√		
	$\theta = 3.3^\circ$	A1	3	

264. 9709_s15_MS_41 Q: 5

	Answer	Mark		Partial Marks
		M1		For using DF = $\frac{P}{v}$ for DF up and down
		M1		For applying Newton's 2nd law up and down
	$\frac{P}{3} - R - 84g \times 0.1 = 84 \times 1.25$	A1		
	$\frac{P}{10} - R + 84g \times 0.1 = 84 \times 1.25$	A1		
	$\left[P\left(\frac{1}{3} - \frac{1}{10}\right) - 168 = 0\right]$	M1		For solving equations for P
	$P = 720$	A1		
	$\left[R = \frac{720}{3} - 84 - 105\right]$	M1		For substitution for P to obtain R
	$R = 51$	A1	8	

265. 9709_s15_MS_42 Q: 1

	Answer	Mark		Partial Marks
(i)	$\left[s = 0.3 \times 5 + \frac{1}{2}\quad 0.5 \times 5^2\right]$ [$v = 0.3 + 0.5 \times 5 = 2.8$m] Complete method for finding s required	M1		For using $s = ut + \frac{1}{2}at^2$ **or** using $v = u + at$ followed by **either** $v^2 = u^2 + 2as$ **or** $s = \frac{(u+v)}{2}t$ **or** $s = vt - \frac{1}{2}at^2$
	Distance = 7.75 m	A1	2	
(ii)	[WD = 8 × 7.75 × 0.5]	M1		For using WD = $Td\cos 60°$
	Work done is 31 J	A1	2	

266. 9709_s15_MS_42 Q: 2

	Answer	Mark		Partial Marks
(i)	$\left[\frac{P}{5} = 80 \times 1.2\right]$	M1		For using DF = $\frac{P}{v}$ and Newton's 2nd law
	$P = 480$	A1	2	
(ii)	$\frac{450}{3.6} - 80g \times 0.035 = 80a$	M1 A1		For using $\frac{P}{v} - W\sin\alpha = ma$
	Acceleration is 1.21 ms^{-2}	A1	3	Allow $a = \frac{97}{80}$

267. 9709_s15_MS_42 Q: 3

	Answer	Mark		Partial Marks
(i)	KE gain $\left[=\frac{1}{2}\times 8\times 4.5^2\right] = 81$ J	B1		
	$\left[\text{Decrease} = 8g\times 12\times\left(\frac{1}{8}\right)\right]$	M1		For using PE = mgh and $h = d\sin\alpha$
	PE loss = 120 J	A1	3	
(ii)	[$81 = 120 - 12R$]	M1		For using KE gain = PE loss –WD by resistance
	Resisting force is 3.25 N	A1	2	Allow $R = \frac{13}{4}$
	Alternative method for (ii)			
(ii)	[$4.5^2 = 2\times a\times 12$] ➔ [$a = \frac{27}{32} = 0.84375$] [$8g\sin\alpha - R = 8\times\frac{27}{32}$]	M1		For using $v^2 = u^2 + 2as$ to find a **and** using Newton's 2nd law to find R
	Resisting force is 3.25 N	A1	2	

268. 9709_s15_MS_43 Q: 1

	Answer	Mark		Partial Marks
	[WD = 500 × 2.75 × 40]	M1		For using WD = Fs or for using WD = Pt
	Work done = 55000 J	A1		
		M1		For using Power = ΔWD÷Δt or for using $P = Fv$
	Power = $\frac{55000}{40}$ = 1375 W or Power = 500 × 2.75 = 1375 W	A1	4	

269. 9709_s15_MS_43 Q: 2

	Answer	Mark		Partial Marks
(i)		B1	1	After B reaches the floor, A continues at constant speed until it reaches the pulley (no tension and the surface is smooth). Thus A's speed when B reaches the floor is the same as A's speed (3 ms^{-1}) when it reaches the pulley. Until the instant when B reached the floor, A and B have the same speed and hence B reaches the floor with speed 3 ms^{-1}.
(ii)	Loss of PE = $0.15gh$ Gain of KE = $\frac{1}{2}(0.35 + 0.15) \times 3^2$ $1.5h = 0.25 \times 9$ $h = 1.5$	B1 B1 M1 A1	4	For using loss of PE = gain of KE
	Alternative Method for part (ii)			
(ii)	[$0.15g - T = 0.15a$ and $T = 0.35a$ or $0.15g = (0.35+0.15)a$] ➔ $a = ...$ $a = 3\text{ms}^{-2}$ [$3^2 = 0 + 2 \times 3h$] $h = 1.5$	M1 A1 M1 A1	4	For applying Newton's second law to A and to B or for using $m_Bg = (m_A+m_B)a$ to find a For using $v^2 = u^2 + 2as$
	Alternative Method for part (ii)			
(ii)	[$0.15g - T = 0.15a$ and $T = 0.35a$] ➔ $T = ...$ $T = 1.05\text{N}$ $\left[0.15gh - \frac{1}{2} \times 0.15 \times 3^2 = 1.05h\right]$ or $\left[\frac{1}{2} \times 0.35 \times 3^2 = 1.05h\right]$ $h = 1.5$	M1 A1 M1 A1	4	For applying Newton's second law to A and to B to find T For using PE_B loss – KE_B gain= WD against T or for using KE_A gain = WD by T

270. 9709_s15_MS_43 Q: 3

	Answer	Mark		Partial Marks
		M1		For using DF = P/v and for applying Newton's 2nd law at one or both points
	$\frac{P}{4.5} - R = 860 \times 4$	A1		
	$\frac{P}{22.5} - R = 860 \times 0.3$	A1		
		M1		For eliminating R to find P or for eliminating P to find R
	$\frac{P}{4.5} - \frac{P}{22.5} = 860(4 - 0.3) \rightarrow$ $P = 17900$ or $-4.5R + 22.5R =$ $860(4 \times 4.5 - 0.3 \times 22.5) \rightarrow$ $R = 537.5$	A1		
	$R = 537.5$	B1	6	Accept 538

271. 9709_s15_MS_43 Q: 4

	Answer	Mark		Partial Marks
	KE loss = $\frac{1}{2} \times 12000(24^2 - 16^2)$ PE gain = $12000g \times 25$	B1 B1		
		M1		For using WD by DF = PE gain – KE loss + WD against resistance
	WD by DF = 3000000 – 1920000 + 7500×500	A1		
		M1		For using DF = WD by DF÷500
	Driving force = 4830000÷500 Driving force is 9660 N	A1	6	
	Alternative Method for 4			
	$[16^2 = 24^2 + 2 \times 500a]$	M1		For using $v^2 = u^2 + 2as$
	$a = -0.32$ ms^{-2}	A1		
	Weight component down hill = $12000g \times 25/500$	B1		
		M1		For using Newton's 2nd law
	$DF - 7500 - 12000g \times \frac{25}{500} = 12000 \times (-0.32)$	A1		
	Driving force is 9660 N	A1	6	

272. 9709_w15_MS_41 Q: 1

	Answer	Mark		Partial Marks
(i)	$200g \times 0.7$	**M1**		For using WD = $mg \times h$
	Work done = 1400 J	**A1**	2	
(ii)	1400 / 1.2	**M1**		For using Power = WD / Time
	Average Power = 1170 W	**A1**√	2	

273. 9709_w15_MS_42 Q: 4

	Answer	Mark		Partial Marks
	Frictional force $= 0.4 \times 2\cos 45$ $= 0.4\sqrt{2}$	M1 A1		For using $R = 2\cos 45^{\circ}$ and $F = \mu R$
	KE gain $= \frac{1}{2} \times 0.2 \times V_C^2$ and PE loss $= 0.2 \times g \times (2.5 + 2\sqrt{2})$	B1		
		M1		For using KE gain from A to C = PE loss from A to C – Work done by frictional force
	$0.1\,V_C^2 = (5 + 4\sqrt{2}) - 0.4\sqrt{2} \times 4$	A1		
	Speed at C is $9.16\,\text{ms}^{-1}$	A1	6	
	First alternative for the last four marks			
	$\frac{1}{2} \times 0.2 \times V_B^2 = 0.2 \times g \times 2.5 \rightarrow V_B^2 = 50$	B1		
		M1		For using KE gain from B to C = PE loss from B to C – Work done by frictional force
	$0.1\,(V_C^2 - V_B^2) = 0.2 \times g \times (4 \div \sqrt{2}) - 0.4\sqrt{2} \times 4$	A1		
	Speed at C is $9.16\,\text{ms}^{-1}$	A1		
	Second alternative for the last four marks			
	$\frac{1}{2} \times 0.2 \times V_B^2 = 0.2 \times g \times 2.5 \rightarrow V_B^2 = 50$	B1		
		M1		For using Newton's 2nd law to find acceleration along BC **and** using $v^2 = u^2 + 2as$ to find V_C
	$\sqrt{2} - 0.4\sqrt{2} = 0.2a \rightarrow a = 3\sqrt{2}\ \text{ms}^{-2}$ and $V_C^2 = V_B^2 + 2 \times 3\sqrt{2} \times 4$	A1		
	Speed at C is $9.16\,\text{ms}^{-1}$	A1		

274. 9709_w15_MS_42 Q: 7

	Answer	Mark		Partial Marks
(i)	[WD = 14000 × 25]	**M1**		For using P = WD÷Δt
	Work done is 350 kJ or 350 000 J	**A1**	2	
(ii)		**M1**		For using DF = P/v and Newton's 2nd law to find the speed of the car at A **or** at B
	$14000/v_A - 235 = 1600 \times 0.5 \rightarrow$ $v_A = 13.53\ \text{ms}^{-1}$	**A1**		$v_A = 2800/207$
	$14000/v_B - 235 = 1600 \times 0.25 \rightarrow$ $v_B = 22.05\ \text{ms}^{-1}$	**A1**		$v_B = 2800/127$
	[KE gain = $\frac{1}{2}\,1600(22.05^2 - 13.53^2)$]	**M1**		For using KE gain $= \frac{1}{2}\,m(v_B^2 - v_A^2)$
	KE gain = 242.5 kJ or 242 500 J	**A1**	5	
(iii)		**M1**		For using WD by DF = KE gain + resistance × AB
	350 000 = 242 500 + 235 × AB	**A1**√		
	Distance AB is 457 m	**A1**	3	

275. 9709_w15_MS_43 Q: 5

	Answer	Mark		Partial Marks
(i)	$a =$ $(5^2 - 3^2) \div (2 \times 500) = 0.016$	B1		
		M1		For using Newton's 2nd law
	$DF + 90g \times 0.05 - R = 90 \times 0.016$	A1		
	$[R = \frac{420}{v} - 90(0.016 - 0.5)]$	M1		For using $DF = P / v$
	$R = \frac{420}{v} + 43.56$	A1	5	AG
				SR for assuming constant R and DF (max 2 / 5) PE loss = 90g(500)(0.05) and KE gain = ½ (90)(5^2–3^2) B1 WD_{DF}+PE loss = KEgain+WD_R $\rightarrow R = 420 / v + 43.56$ B1
(ii)	$v_M^{\ 2} = 3^2 + 2 \times 0.016 \times 250 \rightarrow$ speed at mid-point is 4.12ms^{-1}	B1		
	[Decrease in R from top to mid-way $=420[(1 \div 3) - (1 \div \sqrt{17})]$ or [Decrease in R from midway to b'm = $420[(1 \div \sqrt{17}) - (1 \div 5)]$	M1		For finding the difference in R for either top to midway or midway to bottom
	38.1 and 17.9	A1	3	

276. 9709_w15_MS_43 Q: 7

	Answer	Mark		Partial Marks
(i)	Gain in KE $= \frac{1}{2}\,1250(8^2 - 5^2)$	B1		
	Loss in PE = $1250g \times 400\sin 4°$	B1		
		M1		For using WD by DF = Gain in KE – Loss in PE + WD by resistance
	$400(DF) = \frac{1}{2}\,1250\,(8^2 - 5^2) - 1250g \times 400\sin 4° + 2000 \times 400$	A1		
	Driving force is 1189 N or 1190 N	A1	5	
				SR for using Newton's second law (max 2 / 5) $DF + 1250g\sin 4° - 2000 = 1250a$ B1 $a = (8^2 - 5^2) / 2 \times 400 \rightarrow DF = 1190$ N B1
(ii)		M1		For using Newton's second law to find acceleration or for finding v_C and using $v^2 = u^2 + 2as$ to find acceleration
	$1189 \times 2 - 2000 = 1250a$ or $22.75^2 = 8^2 + 2a \times 750$	A1√		√ DF from part (i)
	Acceleration is 0.302 ms^{-2}	A1	3	
(iii)	$v_c{}^2 = 64 + 2 \times 0.302 \times 750$	B1√		√ acceleration from part (ii)
	[P / 22.75 – 2000 = 1250 × 0.302]	M1		
	Power is 54.1 kW or 54100 W	A1	3	