Q	Scheme	Marks	AOs	Pearson Progression Step and Progress descriptor
1a	$Mg\,x_g = 0.80\times 3g + 1.00\times 4g + 1.40\times 5g$ $x_g = 13.4 \div 12$ $x_g = \frac{67}{60} = 1\frac{7}{60}$	**M1** **M1** **A1**	1.1a 1.1b 1.1b	TBC
		(3)		
1b	Formulates for centre of mass $(m + 12) \times 1.5 = 13.4 + m\,x$ Expands, rearranges and factorises the m terms $18 - 13.4 = m\,x - 1.5\,m$ $m\ (x - 1.5) = 4.6$ Shows given formulae	**M1** **M1** **A1**	2.1 1.1b 2.1	TBC
		(3)		
1c	Reasons $x \leqslant 2$ or mass cannot be placed on rod so substitutes $x = 2$ into formula in **1b** to get $m = 9.2$ kg Explains why therefore $m \geqslant 9.2$ by linking greater mass means smaller x or vice versa	**B1** **B1**	2.4 2.4	TBC
		(2)		
				(8 marks)

Notes

In **1a**, allow for use of cm throughout. Allow without reference to g.

It is important in **1b** that the full flow of logic to reach the given formula is shown; must not be working backwards.

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress descriptor
2	Attempts to find centre of mass of framework from A, taking right and up as the positive directions $1500\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 400\begin{pmatrix}15\\ 0\end{pmatrix} + 400\begin{pmatrix}30\\ -15\end{pmatrix} + 600\begin{pmatrix}15\\ -30\end{pmatrix} + 100\begin{pmatrix}0\\ -15\end{pmatrix}$ Could also use a table or separate workings for x and y	**M1** **A1**	3.1b 1.1b	TBC
	Determines centre of mass of framework correctly So $\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = \begin{pmatrix}18\\ -17\end{pmatrix}$	**A1**	1.1a	
	States or shows that, when in equilibrium, the centre of mass hangs beneath the suspension point OR shows $\tan(\theta) = 17 \div 18$ o.e.	**M1**	1.1b	
	States angle of AB to vertical as $\theta = 43.4°$ to 3 sf	**A1**	3.2a	
		(5)		
				(5 marks)

Notes

Allow method mark for at least three terms on right-hand side.

Other sign conventions and origins can be used.

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress descriptor
3	Converts given angle into radians $60^o = \frac{\pi}{3}$ radians	**M1**	1.1a	TBC
	Substitutes $\alpha = \frac{\pi}{6}$ and $r = 15$ into CoM sector formulae CoM on line of symmetry, distance from centre = $\frac{30}{\pi}$	**B1**	1.1b	
	Uses formulae booklet also for CoM of arc with same values CoM of arc (with plastic edging) also on the line of symmetry, distance from centre = $\frac{45}{\pi}$	**B1**	1.1b	
	Uses above and given masses in 1D to find composite CoM $450 \times \frac{30}{\pi} + 150 \times \frac{45}{\pi} = 600\ \bar{x}$ so $\bar{x} = 33.75\ \pi$ from centre o.e.	**M1** **A1**	3.2a	
				(5 marks)
Notes				

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress descriptor
4a	Quotes formulae booklet that centre of mass of triangle is $\frac{2}{3}$ of median from apex, so that length of median is $3 \times 0.2 = 0.6$ m	**M1**	1.1a	TBC
	Uses properties of right-angled isosceles triangles to state that hypotenuse of lamina must be 1.2 m	**M1**	3.1b	
	Correctly calculates area of triangular surface $0.6 \times 1.2 \div 2 = 0.36$ m^2 o.e.	**A1**	1.1b	
		(3)		
4b	EITHER Uses density to calculate mass of lamina $3600 \times 1.42 = 5112$ g	**M1**	3.1b	TBC
	Uses 1D line of symmetry to find new centre of mass $(0.2 \times 5.112 + 0.6 \times 0.5) \div 5.612 = 0.2356...$ m o.e.	**M1**	1.1b	
	Calculates distance moved correctly to nearest mm Centre of mass moved by 36 mm o.e. (towards apex)	**A1**	1.1b	
	OR Uses density to calculate mass of lamina $3600 \times 1.42 = 5112$ g	**M1**	3.1b	
	$(5.112+0.5)\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = 5.112\begin{pmatrix}0.4\cos 45°\\ 0.4\sin 45°\end{pmatrix} + 0.5\begin{pmatrix}0\\0\end{pmatrix}$ $\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix} = \begin{pmatrix}0.2576...\\ 0.2576...\end{pmatrix}$	**M1**	1.1b	
	Calculates distance between $\begin{pmatrix}0.2576...\\ 0.2576...\end{pmatrix}$ and $\begin{pmatrix}0.4\cos 45°\\ 0.4\sin 45°\end{pmatrix}$ $= 0.036$ m	**A1**	1.1b	
		(3)		
				(6 marks)

Notes

If **3a** is attempted using the given answer, a convincing argument must be given.

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress descriptor
5a	Calculates area and centre of mass of **rectangle** correctly area = $12 \times 25 = 300$ cm^2 and CoM from $O = \begin{pmatrix} 16 + 0.5 \times 25 \\ -6 \end{pmatrix} = \begin{pmatrix} 28.5 \\ -6 \end{pmatrix}$ o.e.	**B1**	3.1b	TBC
	Calculates area and centre of mass of **triangle inc *O*** correctly area = $12 \times 16 \div 2 = 96$ cm^2 and CoM from $O = \begin{pmatrix} 8 + \frac{1}{3} \times 8 \\ -\frac{1}{3} \times 12 \end{pmatrix} = \begin{pmatrix} \frac{32}{3} \\ -4 \end{pmatrix}$ o.e.	**B1** **B1**	1.1b	
	Calculates area and centre of mass of **other triangle** correctly Finds the base of the triangle = $\sqrt{13^2 - 12^2} = 5$ area = $12 \times 5 \div 2 = 30$ cm^2 and CoM from $O = \begin{pmatrix} 16 + 25 + \frac{2}{3} \times 5 \\ -\frac{2}{3} \times 12 \end{pmatrix} = \begin{pmatrix} \frac{133}{3} \\ -8 \end{pmatrix}$ o.e.	**B1** **B1** **B1**	1.1b	TBC
	Uses total area and above to find centre of mass of lamina $300 \begin{pmatrix} 28.5 \\ -6 \end{pmatrix} + 96 \begin{pmatrix} 10.\dot{6} \\ -4 \end{pmatrix} + 30 \begin{pmatrix} 43.\dot{3} \\ -8 \end{pmatrix} = 426 \begin{pmatrix} x \\ y \end{pmatrix}$ So CoM from *O* is (25.596, −5.690) o.e. allow correct to 1 dp	**M1** **A1 ft**	3.2a	
		(8)		

5b	Centre of mass to be at the point (23, −6)	**B1**	3.1b	TBC
	Finds mass of drilled out circle = $\pi \times 16 \times 1.4 = 70.4$ to 1 dp	**M1**	1.1a	
	Uses 2D system for the question (or table or separate), $426\begin{pmatrix}25.596\\5.7\end{pmatrix} - 16\pi\begin{pmatrix}x\\y\end{pmatrix} = 37507\begin{pmatrix}23\\6\end{pmatrix}$	**M1**	1.1b	
	Solves to find centre of circle position from A, $\begin{pmatrix}x\\y\end{pmatrix} = \begin{pmatrix}44.2\\3.5\end{pmatrix}$	**A1** **A1**	1.1b	
	Circle's centre lies outside of surface of trapezium so impossible	**A1**	2.4	
		(6)		
				(14 marks)
	Notes			

Q	Scheme	Marks	AOs	Pearson Progression Step and Progress descriptor
6a	Quotes centre of mass of **square** = (3.5, 3.5) o.e.	**M1**	3.1a	TBC
	Calculates area and centre of mass of **top semi circle** correctly: CoM of sector angle 2α when $a = \frac{\pi}{2}$ and r = 3.5 cm Area = $\pi \times 3.5^2 \div 2 = 19.24$ cm^2 and CoM = $(3.5, -\frac{14}{3\pi})$ o.e.	**M1**	1.1b	
	Calculates the centre of mass of **other semi-circle** correctly CoM = $(\frac{14}{3\pi}, 3.5)$ o.e.	**M1**	1.1b	
	Using total area and above find lamina CoM (or table or separate) $49\begin{pmatrix}3.5\\3,5\end{pmatrix} + 19.24\begin{pmatrix}3.5\\-1.49\end{pmatrix} + 19.24\begin{pmatrix}-1.49\\3.5\end{pmatrix} = 87.48\begin{pmatrix}x\\y\end{pmatrix}$	**M1**	1.1b	
	Calculates centre of mass of lamina $\begin{pmatrix}x\\y\end{pmatrix} = \begin{pmatrix}2.403\\2.403\end{pmatrix}$	**A1**	3.2a	
		(5)		

6b	Using total mass and above, find expression for combined CoM with either **i** or **j** vector component correct, $1.8\begin{pmatrix}2.4\\2.4\end{pmatrix}+3m\begin{pmatrix}0\\3.5\end{pmatrix}+4m\begin{pmatrix}3.5\\0\end{pmatrix}=(1.8+7m)\begin{pmatrix}x\\y\end{pmatrix}$	**M1**	3.3	TBC
	Full correct expression as above.	**M1**	3.3	
	So, $\begin{pmatrix}x\\y\end{pmatrix}=\frac{1}{7m+1.8}\begin{pmatrix}14m+4.32\\10.5m+4.32\end{pmatrix}$ (allow 1 dp rounding)	**A1**	3.4	
	Reasons angle from vertical mean 45 – 3 = 42 from horizontal	**M1**	2.4	
	Applies trigonometry in context of model correctly, $\frac{10.5m+4.32}{14m+4.32}=\tan(42)=0.9$	**M1**	3.4	
	Rearranges to find m, $10.5m + 4.32 = 12.61m + 3.89$ $m = 0.2$ g (to 1 dp)	**M1**	1.1a	
	States mass of diamond = 0.6 g to 1 dp	**A1**	3.2a	
		(7)		
				(12 marks)

Notes

In **6a** candidate may work out x only and use symmetry to know y value for CoM is the same.