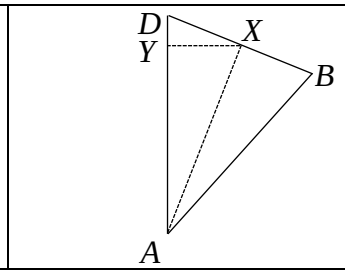
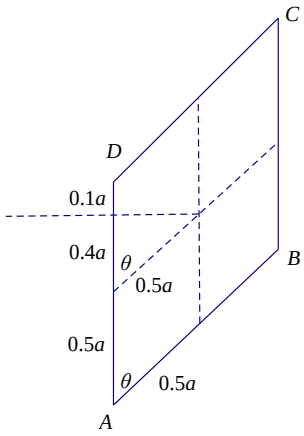
| Question Number | Scheme | Marks |
|---|---|---|
| **4(a)** | Vertical distance from $A$ to $C$ is $a + a\cos\theta$ | B1 |
| | "Half the vertical height of the diagram"<br>Using the symmetry of the figure, the centres of mass of the rhombuses lie on a straight line passing through the centre of mass. | M1 |
| | $0.9a = \frac{1}{2}(a + a\cos\theta)$ | A1<br>A1 |
| | $\cos\theta = 0.8$ ***** | A1* |
| | | (5) |
| **Alt1** | Distance from $A$ to centre of rhombus = $a\cos\frac{\theta}{2}$ | B1 |
| | "Moments using CoM of two rhombuses"<br>Taking moments about an axis through $A$ parallel to $FB$ | M1 |
| | $\lambda.a\cos\frac{\theta}{2}.\cos\frac{\theta}{2} + \lambda.a\cos\frac{\theta}{2}\cos\frac{\theta}{2} = 2\lambda \times 0.9a$ | A1<br>A1 |
| | $\cos\theta = 2\cos^2\frac{\theta}{2} - 1 = 0.8$ ***** | A1* |
| | | (5) |
| **Alt2** | Distance from $A$ to centre of rhombus (= $AX$ =) $a\cos\frac{\theta}{2}$ | B1 |
| | "Vertical height of CoM rhombus"<br>Using the symmetry of the figure, the centres of mass of the rhombuses lie on a straight line passing through the centre of mass: $AY = AX\cos\frac{\theta}{2}$<br><br> | M1 |
| | $a\cos\frac{\theta}{2} \times \cos\frac{\theta}{2} = 0.9a$ | A1<br>A1 |
| | $\cos\theta = 2\cos^2\frac{\theta}{2} - 1 = 0.8$ ***** | A1* |
| | | (5) |
| **Alt3** | <table><tr><td>Shape</td><td>$EFBC$</td><td>$EDC$</td><td>$FAB$</td><td>lamina</td></tr><tr><td>Mass/Area</td><td>$2a^2\sin\theta$</td><td>$a^2\sin\theta\cos\theta$</td><td>$a^2\sin\theta\cos\theta$</td><td>$2a^2\sin\theta$</td></tr><tr><td>CoM</td><td>$a\cos\theta + \frac{a}{2}$</td><td>$a + \frac{2}{3}a\cos\theta$</td><td>$\frac{2}{3}a\cos\theta$</td><td>$0.9a$</td></tr></table> | B1 |
| | Moments equation ("Rectangle minus triangle plus triangle") | M1 |
| | $2a^2\sin\theta\left(a\cos\theta + \frac{a}{2}\right) - a^2\sin\theta\cos\theta\left(\frac{2}{3}a\cos\theta + a - \frac{2}{3}a\cos\theta\right) = 2a^2\sin\theta \times 0.9a$ | A1<br>A1 |
| | $\cos\theta = 0.8$ ***** | A1* |
| | | (5) |

<table>
<tr><td>Alt4</td><td>
<table>
<tr><td>Shape</td><td>EDF & BCD</td><td>AFD & ADB</td><td>lamina</td></tr>
<tr><td>Mass/Area</td><td>$2\times\frac{1}{2}a^2\sin\theta$</td><td>$2\times\frac{1}{2}a^2\sin\theta$</td><td>$2a^2\sin\theta$</td></tr>
<tr><td>CoM</td><td>$\frac{2}{3}a(1+\cos\theta)$</td><td>$\frac{1}{3}a(1+\cos\theta)$</td><td>$0.9a$</td></tr>
</table>
</td><td>B1</td></tr>
<tr><td></td><td>Moments equation (“two upper triangles and two lower triangles”)</td><td>M1</td></tr>
<tr><td></td><td>$2\times\frac{1}{3}a(1+\cos\theta)\times\frac{1}{2}a^2\sin\theta+2\times\frac{2}{3}a(1+\cos\theta)\times\frac{1}{2}a^2\sin\theta=2a^2\sin\theta\times0.9a$</td><td>A1<br>A1</td></tr>
<tr><td></td><td>$\cos\theta=0.8$ **</td><td>A1*</td></tr>
<tr><td></td><td></td><td>(5)</td></tr>
<tr><td>Alt5</td><td>$AM=a\cos\theta$ (where M is the midpoint of BF)</td><td>B1</td></tr>
<tr><td></td><td>“Midpoint of midpoints”<br>CoM lies at midpoint of DM</td><td>M1</td></tr>
<tr><td></td><td>$0.9a=a\cos\theta+\frac{1}{2}(a-a\cos\theta)$</td><td>A1<br>A1</td></tr>
<tr><td></td><td>$\cos\theta=0.8$ **</td><td>A1*</td></tr>
<tr><td></td><td></td><td>(5)</td></tr>
<tr><td>Alt6</td><td>“Working out the heights and trigonometry”<br>
</td><td></td></tr>
<tr><td></td><td>$0.4a$ seen or implied</td><td>B1</td></tr>
<tr><td></td><td>Use of line of centres of rhombuses and trigonometry</td><td>M1</td></tr>
<tr><td></td><td>$\cos\theta=\frac{0.4a}{0.5a}$</td><td>A1<br>A1</td></tr>
<tr><td></td><td>$\cos\theta=0.8$ **</td><td>A1*</td></tr>
<tr><td></td><td></td><td>(5)</td></tr>
<tr><td>4(b)</td><td>Taking moments about B:</td><td>M1</td></tr>
<tr><td></td><td>$kW(a\cos\theta)=W(0.9a-a\cos\theta)$</td><td>A1<br>A1</td></tr>
<tr><td></td><td>$k=\frac{1}{8}$</td><td>A1</td></tr>
<tr><td></td><td></td><td>(4)</td></tr>
</table>

| | | |
|---|---|---|
| **Alt** | Taking moments about $A$: | M1 |
| | $0.9aW = (k+1)W \times a\cos\theta = (k+1)\times 0.8aW$ | A1<br>A1 |
| | $k = \frac{1}{8}$ | A1 |
| | | (4) |
| | | **(9 marks)** |

| **Notes** | |
|---|---|
| *N.B. Be aware that candidates may have worked on a diagram on the question paper and may use their own labelling.* | |
| (a) B1 | $a + a\cos\theta$ seen |
| M1 | Use of the symmetry of the figure for the height. Condone sin/cos confusion. |
| A1 | Unsimplified equation with at most one error. |
| A1 | Correct unsimplified equation. |
| A1* | Obtains given answer from correct exact working. |
| | |
| Alt1 B1 | May be marked on a diagram |
| M1 | Taking moments about an axis through $A$ parallel to $FB$. Correct number of terms and dimensionally consistent. Condone sin/cos confusion. Any correct ratios in place of $\lambda$; may frequently see $a^2\sin\theta$. |
| A1 | Unsimplified equation with at most one error. |
| A1 | Correct unsimplified equation. $\left(\cos^2\frac{\theta}{2} = 0.9\right)$ |
| A1* | Obtains given answer from correct exact working. |
| | |
| Alt2 B1 | May be marked on a diagram |
| M1 | Use of the symmetry of the figure for the height. Condone sin/cos confusion. |
| A1 | Unsimplified equation with at most one error. |
| A1 | Correct unsimplified equation. $\left(\cos^2\frac{\theta}{2} = 0.9\right)$ |
| A1* | Obtains given answer from correct exact working. |
| | |
| Alt3 B1 | Correct division of lamina with correct mass ratios<br>Penalise errors in distance via the moments equation |
| M1 | Moments equation about axis parallel to $FB$. Correct number of terms and dimensionally consistent. Condone sin/cos confusion. |
| A1 | Unsimplified equation with at most one error. |
| A1 | Correct unsimplified equation. |
| A1* | Obtains given answer from correct exact working. |
| | |
| Alt4 B1 | Correct division of lamina with correct mass ratios<br>Penalise errors in distance via the moments equation |
| M1 | Moments equation about axis parallel to $FB$. Correct number of terms and dimensionally consistent. Condone sin/cos confusion. |
| A1 | Unsimplified equation with at most one error. |
| A1 | Correct unsimplified equation. |
| A1* | Obtains given answer from correct exact working. |

| | |
|---|---|
| | |
| Alt5 B1 | May be marked on a diagram |
| M1 | Use of the symmetry of the figure for the height. Condone sin/cos confusion. |
| A1 | Unsimplified equation with at most one error. |
| A1 | Correct unsimplified equation. |
| A1* | Obtains given answer from correct exact working. |
| | |
| Alt6 B1 | May be on a diagram (seen or implied). Could be implied by use of $0.1a$. |
| M1 | Use of the symmetry of the figure: the CoM lies on a line joining the centres of the rhombuses. Condone sin/cos confusion. |
| A1 | Unsimplified equation with at most one error. |
| A1 | Correct unsimplified equation. |
| A1* | Obtains given answer from correct exact working. |
| | |
| (b) M1 | Moments about *B*. Must have both terms but condone sign errors and sin/cos confusion. |
| A1 | Unsimplified equation with at most one error. |
| A1 | Correct unsimplified equation. ($0.8kW = 0.1W$) |
| A1 | Cao |
| | |
| Alt M1 | Moments about *A* and use of CoM on *FB*. Must have correct number of terms but condone sign errors and sin/cos confusion. |
| A1 | Unsimplified equation with at most one error. |
| A1 | Correct unsimplified equation. |
| A1 | Cao |
| | |
| **N.B.** | If a candidate does not specify the point about which they are taking moments, do not condone a "mixed approach". E.g. "$kW\left(a\cos\theta\right) = 0.9aW$" is M0 |

**5**

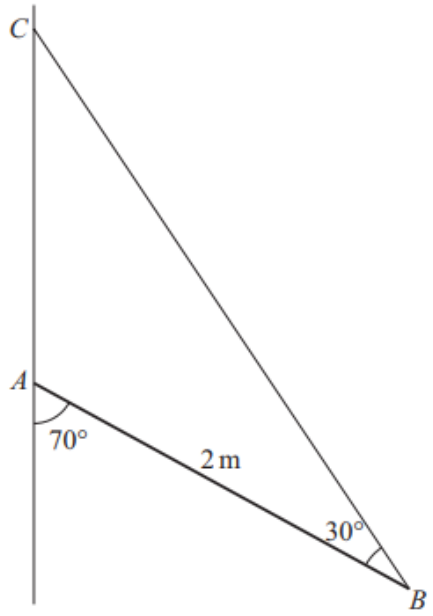



**Figure 2**

A uniform rod $AB$ has mass 6 kg and length 2 m. The end $A$ of the rod rests against a rough vertical wall.

One end of a light string is attached to the rod at $B$. The other end of the string is attached to the wall at $C$, which is vertically above $A$.

The angle between the rod and the string is 30° and the angle between the rod and the wall is 70°, as shown in Figure 2.

The rod is in a vertical plane perpendicular to the wall and rests in limiting equilibrium.

Find

(a) the tension in the string,

**(4)**

(b) the coefficient of friction between the rod and the wall,

**(5)**

(c) the direction of the force exerted on the rod by the wall at $A$.

**(2)**

**(Total for Question 5 is 11 marks)**