Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 The angles of three forces

ANSWER A · 4

Tests: the angle between two forces is 180° minus the triangle's angle between their sides; Lami's theorem with the right pairs (the tempting answer takes the triangle's angle as it is).

a. In the triangle, the angle between the sides 3 and 5 (opposite 7): $\cos C = \frac{9+25-49}{30} = -\frac{1}{2}$, $C = 120°$. Drawn head to tail, the forces turn through the triangle's outside angle, so the angle between the forces is $180° - 120° = \mathbf{60}°$: she is wrong.

b. The triangle's other angles: opposite 3, $\cos A = \frac{25+49-9}{70}$, $A = 21.8°$; opposite 5, $B = 38.2°$. Between the forces: 5 N and 7 N at $180° - 21.8° = \mathbf{158.2}°$; 3 N and 7 N at $180° - 38.2° = \mathbf{141.8}°$ (and $60 + 158.2 + 141.8 = 360$ ✓).

Lami: $\frac{3}{\sin 158.2°} = \frac{5}{\sin 141.8°} = \frac{7}{\sin 60°} = 8.08$ ✓.

MARKING SCHEME

- ✓ The triangle's angle 120°, so 60° between the forces: she is wrong.
- ✓ 158.2° between 5 N and 7 N.
- ✓ 141.8° between 3 N and 7 N.
- ✓ Lami's ratios all 8.08.

2 The least force

ANSWER HA · 5

Tests: Lami's theorem with an unknown angle, read as a function; the least force is at right angles to the string, not horizontal (the tempting answer: $W\tan 30° = 28.9$ N is the least).

a. $P = 50\tan 30° = \mathbf{28.9\ N}$, $T = 50\sec 30° = \mathbf{57.7\ N}$.

b. The string makes 150° with the weight (the angle between T and W). Lami: $\frac{P}{\sin 150°} = \frac{W}{\sin\theta}$, the angle between T and P being θ. So $P = \frac{50 \times \frac{1}{2}}{\sin\theta} = \frac{25}{\sin\theta}$.

c. Least when $\sin\theta = 1$, $\theta = 90°$: $P = \mathbf{25\ N}$, **at right angles to the string** (30° above the horizontal). Then the angle between T and P is 90°, and between P and W it is $360° - 150° - 90° = 120°$: $\frac{T}{\sin 120°} = \frac{50}{\sin 90°}$, $T = \mathbf{43.3\ N}$. The horizontal pull ($\theta = 120°$) needs 28.9 N.

MARKING SCHEME

- ✓ Horizontal: 28.9 N and 57.7 N.
- ✓ Lami with the 150° between T and W.
- ✓ $P = \frac{25}{\sin\theta}$.
- ✓ Least 25 N at $\theta = 90°$, at right angles to the string.
- ✓ $T = 43.3$ N.

3 A ring on a string

ANSWER

Tests: one tension through a smooth ring, so equal angles (balancing the horizontal parts); $\sin\alpha = \frac{\text{span}}{\text{length}}$, whatever the heights (the tempting answer: lowering a hook changes the angles).

a. The ring is smooth, so the string runs freely and the tension is the same T in both parts. The horizontal parts $T\sin\alpha_1$ and $T\sin\alpha_2$ must balance, so $\alpha_1 = \alpha_2$.

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b. The horizontal reach of both parts is $5\sin\alpha = 4$: $\sin\alpha = 0.8$, $\alpha = 53.1°$. $2T\cos\alpha = 30$: $T = \dfrac{30}{2 \times 0.6} = \mathbf{25\ N}$. HA · 5

c. Still one tension, still equal angles, still $5\sin\alpha = 4$: **the same 53.1° and 25 N**. Only the ring's place changes: with parts $l_1 + l_2 = 5$ and $(l_1 - l_2)\cos\alpha = 1$ (the hooks' difference in height), $l_1 - l_2 = \dfrac{1}{0.6}$: $l_1 = 3.33$ m from the higher hook, $l_2 = 1.67$ m. The ring is 2.67 m across from the higher hook and 2 m below it.

MARKING SCHEME

- ✓ One tension, so equal angles from the horizontal balance.
- ✓ $\sin\alpha = 0.8$, 53.1°.
- ✓ $T = 25$ N.
- ✓ The same angle and tension after the hook is lowered.
- ✓ The ring 3.33 m along the string from the higher hook (2.67 m across, 2 m down).

4 Two porters and a plank

ANSWER A · 5

Tests: like parallel forces and their resultant; moments about a point (the tempting answer in a.: 150 N each, as if the load were in the middle).

a. Moments about A: $F_2 \times 4 = 200 \times 2 + 100 \times 1 = 500$: $\mathbf{F_2 = 125\ N}$; $F_1 = 300 - 125 = \mathbf{175\ N}$. Porter 1 carries more, being nearer the sack.

b. Equal loads: 150 N each. Moments about A: $150 \times x = 500$, $\mathbf{x = 3.33\ m}$ **from A** (0.67 m in from B).

c. Like parallel forces 200 N at 2 m and 100 N at 1 m: resultant **300 N** downward, at $\dfrac{500}{300} = \mathbf{1.67\ m}$ **from A** (where $200 \times 0.33 = 100 \times 0.67$). That is why b.'s porters stand equally far, 1.67 m, on either side of it.

MARKING SCHEME

- ✓ Moments about A: 500 N m.
- ✓ 125 N and 175 N.
- ✓ 3.33 m from A.
- ✓ Resultant 300 N.
- ✓ At 1.67 m from A.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	0	9	10	**19**

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