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SOLUTIONS
ATTEMPT | CHECK | CORRECT | IMPROVE

AQA AS Vectors, Equilibrium and Moments solutions

Matching solutions and teaching prompts for the class review

Specification points covered

• 3.4.1.1(a–b) Scalars, vectors and vector representation. • 3.4.1.1(c–d) Addition and resolution of vectors. • 3.4.1.1(e–j) Resultant forces and equilibrium of coplanar forces. • 3.4.1.2(a) Moment of a force.	• 3.4.1.2(b) Principle of moments. • 3.4.1.2(c) Couples and torque. • 3.4.1.2(d–f) Centre of mass, support forces and stability.

Teaching focus

Require a direction with every vector result.
Keep force equilibrium and moment equilibrium as separate checks.

1. Vector audit

1. Classify each quantity as scalar or vector: mass, speed, displacement and force. [4 marks]

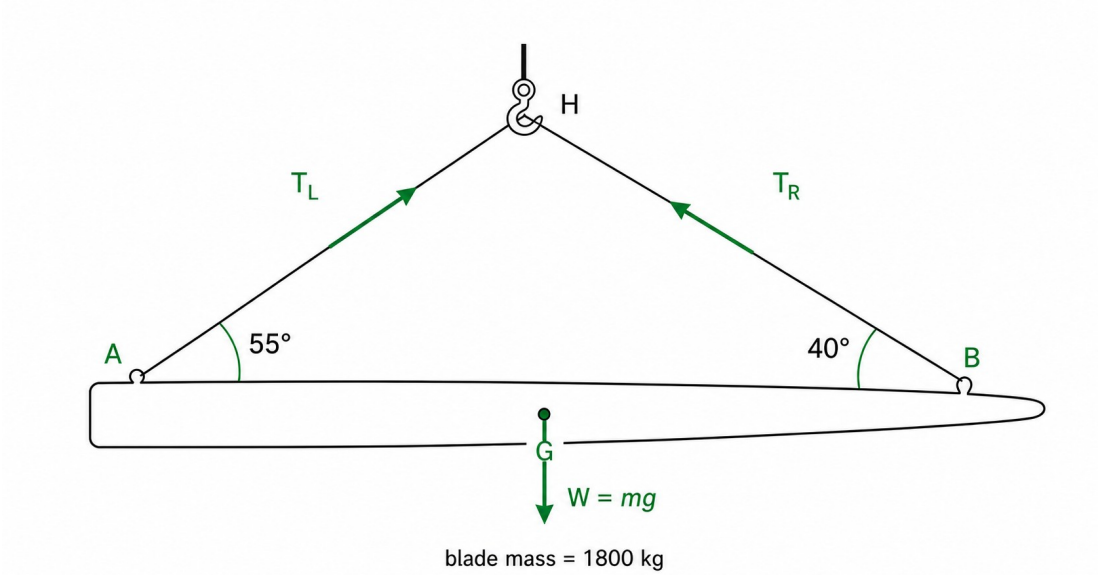
Answer / mark points: Mass and speed are scalars. Displacement and force are vectors.
Teacher prompt / common error: A quantity with magnitude only is scalar; do not classify speed as a vector.

2. A service boat travels 1.20 km east and then 0.900 km north. Calculate the magnitude and direction of its resultant displacement. [3 marks]

Answer / mark points: Magnitude = $\sqrt{(1.20^2 + 0.900^2)} = 1.50$ km. $\tan\theta = 0.900/1.20$, so $\theta = 36.9°$ north of east.
Teacher prompt / common error: Give both a magnitude and a referenced direction.

2. Lifting the blade

3. The figure shows a stationary 1800 kg turbine blade suspended by two cables. Copy or annotate the diagram to show every force acting on the blade. Each force arrow must start at an appropriate point and have a label. [3 marks]



Answer / mark points: Three forces act on the blade: its weight W = mg vertically downward through G; the left-cable tension along the left cable towards H; and the right-cable tension along the right cable towards H.
Teacher prompt / common error: Tension acts along a cable and pulls away from the blade; weight acts through G.

4. The left and right cables make angles of 55.0° and 40.0° to the horizontal. By resolving forces horizontally and vertically, calculate the tension in each cable. [4 marks]

Answer / mark points: Horizontal equilibrium gives $T_{left} \cos 55.0° = T_{right} \cos 40.0°$. Vertical equilibrium gives $T_{left} \sin 55.0° + T_{right} \sin 40.0° = 1800 \times 9.81$. Solving gives $T_{left} = 13.6$ kN and $T_{right} = 10.2$ kN.
Teacher prompt / common error: Use separate horizontal and vertical equilibrium equations.

3. Equilibrium on supports

5. State the two conditions for a rigid body to be in equilibrium. Explain why equilibrium does not always mean that an object is stationary. [2 marks]

Answer / mark points: The resultant force is zero and the resultant moment about any point is zero. A body in equilibrium may be at rest or may move with constant velocity without rotating faster or slower.
Teacher prompt / common error: Zero resultant force prevents linear acceleration; zero resultant moment prevents angular acceleration.

6. Each lifting cable has a working tension limit of 18.0 kN. Determine the smallest safety factor during the lift, using your answers to Question 4. [2 marks]

Answer / mark points: The smallest factor occurs for the larger tension: safety factor = 18.0/13.6 = 1.33.
Teacher prompt / common error: Use the largest actual tension because it gives the smallest safety factor.

7. Define the moment of a force about a point. State precisely which distance is used in the calculation. [2 marks]

Answer / mark points: Moment about a point = force × perpendicular distance from the point to the force's line of action. The shortest perpendicular distance is required.
Teacher prompt / common error: The distance is to the line of action, not automatically to where the force is drawn.

8. The blade is then placed horizontally on supports A and B at positions 1.0 m and 10.0 m from its root. Its centre of mass is 5.0 m from the root. Calculate the vertical reaction force at each support. [4 marks]

Answer / mark points: Taking moments about A: $R_B \times 9.0 = (1800 \times 9.81) \times 4.0$, so $R_B = 7.85$ kN. Vertical equilibrium gives $R_A = 17.66 - 7.85 = 9.81$ kN.
Teacher prompt / common error: Use the 9.0 m separation between supports, then apply vertical equilibrium.

4. Controlling rotation and stability

9. A 400 kg test fixture is attached 9.0 m from the root while the 1800 kg blade has its centre of mass 5.0 m from the root. Calculate the position of the combined centre of mass from the root. [3 marks]

Answer / mark points: x = (1800 × 5.0 + 400 × 9.0)/(1800 + 400) = 5.73 m from the root.
Teacher prompt / common error: Take a mass-weighted mean position; g cancels.

10. A technician applies a couple using two equal and opposite 250 N forces whose parallel lines of action are 1.40 m apart. Calculate the moment of the couple. [2 marks]

Answer / mark points: Moment of the couple = one force × perpendicular separation = 250 × 1.40 = 350 N m.
Teacher prompt / common error: Do not double the force in the couple formula.

11. A mobile crane has a restoring weight of 120 kN acting 2.50 m to the left of an outrigger pivot. Its suspended load acts 6.00 m to the right of the pivot. Calculate the greatest load force before tipping and determine the moment safety margin when the load is 35.0 kN. [3 marks]

Answer / mark points: At tipping: 120 × 2.50 = F_{load} × 6.00, so F_{load} = 50.0 kN. With 35.0 kN, the restoring moment is 300 kN m and the overturning moment is 210 kN m, giving a 90 kN m margin.
Teacher prompt / common error: At the tipping limit the reaction at the other support has fallen to zero.

12. A component of weight 850 N rests in equilibrium on a smooth slope at 12.0° to the horizontal, held by a cable parallel to the slope. Calculate the cable tension and the normal contact force. [3 marks]

Answer / mark points: Along the slope, T = 850 sin 12.0° = 177 N. Perpendicular to the slope, R = 850 cos 12.0° = 831 N.
Teacher prompt / common error: On a smooth slope there is no friction; resolve weight parallel and perpendicular to the surface.

5. Planning a safe lift

13. The lift supervisor can move the cable attachment points, change the cable angles or add a spreader beam. Explain how vectors, moments and centre of mass should be used to choose a stable lifting arrangement. Include the effect of making a cable more horizontal and explain how the team should check against the tension limits. [5 marks]

Answer / mark points: Award any five linked points: resolve each tension into horizontal and vertical components; vertical components must support the total weight and horizontal components must cancel; a more horizontal cable has a smaller vertical component for a given tension so a larger tension is required; place attachment points so the centre of mass remains below the hook or inside the support region; require zero resultant moment to avoid rotation; calculate every cable tension and compare the largest with its permitted working value and safety factor; a spreader beam can improve cable angles or distribute forces.

Teacher prompt / common error: A flatter cable does not make the lift easier: it increases the tension needed for the same vertical support.

Language and method check

Award independent, creditworthy physics steps; do not award extra marks for repeated statements.
Accept equivalent methods when the physical reasoning, units and final precision remain consistent.