

Moments levers and gears

AQA GCSE Physics 8463 only | Paper 2 | Foundation and Higher
Worked solutions and teaching prompts | Separate Physics both tiers

Specification points covered

8463 4.5.4: moment of a force and perpendicular distance, $M = Fd$
8463 4.5.4: balance of clockwise and anticlockwise moments
8463 4.5.4: levers and gears transmitting the turning effects of forces
Separate Physics only; not a required Combined Science Trilogy topic

A maintenance team services a lifting platform, balances a pivoted tool tray and checks a gear drive. Each test is separate. Use $M = Fd$, with M in N m , F in N and perpendicular distance d in m . For balance, total clockwise moment equals total anticlockwise moment about the same pivot.

All parts assess Separate Physics content for both tiers. Accept equivalent precise wording and sensible follow-through. Suggested timing is not classroom-tested. Original PhysicsUK questions, not an official AQA paper or mark scheme.

1 Getting the turning effect right

Before the tests, the team checks how to describe a lever's turning effect.

1(a) What is meant by the moment of a force? **[1 mark]**

Answer / mark points: The turning effect of a force about a pivot. [1]

1(b) In $M = Fd$, what distance does d represent? **[1 mark]**

Answer / mark points: The perpendicular distance from the pivot to the line of action of the force. [1]

Teacher prompt: Distance from the pivot to the end of the object is not a general definition.

1(c) A technician must produce the same turning effect on a hatch with a smaller perpendicular force. Explain where along the fixed handle the force should be applied and why. **[2 marks]**

Answer / mark points: Apply the force farther from the pivot, increasing its perpendicular distance. [1]

For the same required moment, a larger d means a smaller F is needed because $M = Fd$. [1]

Teacher prompt: Name the force's point or line of action. Longer handle alone does not establish a larger moment arm.



2 Checking the service lever

Figure 1 shows a handle pivoted at O. Only the applied test force is shown. The 40 N force acts vertically down at P, not at the end Q. Ignore friction at the pivot.

$$M = 40 \times 0.45 = 18 \text{ N m}$$

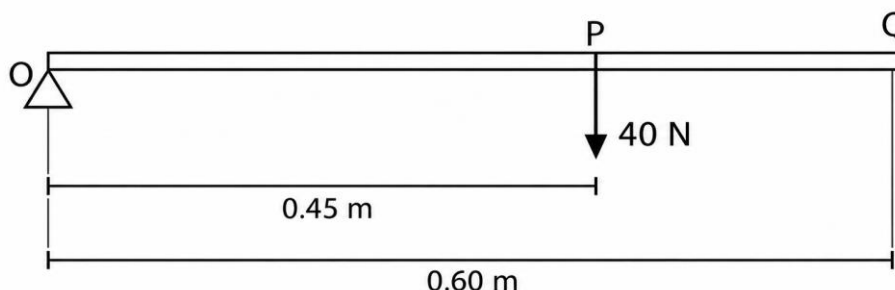


Figure 1

2(a) A trainee uses 0.60 m with the 40 N force in Figure 1. State the correct distance and calculate the moment of that force about O. **[2 marks]**

Answer / mark points: Use $d = 0.45 \text{ m}$, from O to the vertical line through P. [1]
 $M = 40 \times 0.45 = 18 \text{ N m}$. [1]

2(b) State whether the force shown tends to turn the handle clockwise or anticlockwise about O. **[1 mark]**

Answer / mark points: Clockwise. [1]

2(c) The same 40 N force is applied vertically down at Q instead of P. Calculate the increase in its moment about O. **[2 marks]**

Answer / mark points: New moment = $40 \times 0.60 = 24 \text{ N m}$. [1]
 Increase = $24 - 18 = 6 \text{ N m}$. [1]

2(d) Calculate the downward force at Q that would produce the original 18 N m moment. **[1 mark]**

Answer / mark points: $F = M / d = 18 / 0.60 = 30 \text{ N}$. [1]

2(e) The force at P is now horizontal, along the handle towards O. Explain why its moment about O is zero, although P has not moved. **[2 marks]**

Answer / mark points: Its line of action passes through O, so the perpendicular distance is zero. [1]
 $M = F \times 0 = 0 \text{ N m}$, so it has no turning effect about O. [1]

Teacher prompt: The non-zero distance OP along the handle is not the perpendicular distance for this horizontal force.



3 Choosing a usable handle

The team checks several separate hatch and clamp mechanisms. In each test, the stated distance is perpendicular to the force's line of action.

3(a) A hatch is pushed with 75 N at a perpendicular distance of 0.24 m. Calculate the moment. **[1 mark]**

Answer / mark points: $M = Fd = 75 \times 0.24 = 18 \text{ N m}$. [1]

3(b) A clamp handle is pushed with 100 N at 0.12 m from its pivot. Calculate the moment. **[1 mark]**

Answer / mark points: $M = Fd = 100 \times 0.12 = 12 \text{ N m}$. [1]

3(c) A second clamp needs a moment of 21 N m. Its perpendicular force acts 350 mm from the pivot. Calculate the force needed. **[2 marks]**

Answer / mark points: $d = 350 / 1000 = 0.350 \text{ m}$. [1]

$F = M / d = 21 / 0.350 = 60 \text{ N}$. [1]

3(d) A hatch must be turned with a moment of 20 N m using an 80 N perpendicular force. Calculate the required distance from the pivot. **[1 mark]**

Answer / mark points: $d = M / F = 20 / 80 = 0.25 \text{ m}$. [1]

3(e) Another hatch needs 21 N m. The operator can apply at most 70 N. Available perpendicular handle distances are 0.20 m, 0.30 m and 0.40 m. Select the shortest suitable one and justify it with calculations. **[2 marks]**

Answer / mark points: At 0.30 m, $F = 21 / 0.30 = 70 \text{ N}$, so it meets the limit. [1]

At 0.20 m, $F = 21 / 0.20 = 105 \text{ N}$, above the limit; therefore 0.30 m is the shortest suitable choice. [1]

Teacher prompt: 0.40 m would also work at 52.5 N, but it is not the shortest suitable handle.

3(f) A trainee adds an extension beyond the hand grip, but keeps the pivot, applied force and its line of action unchanged. Does this increase the moment? Explain. **[1 mark]**

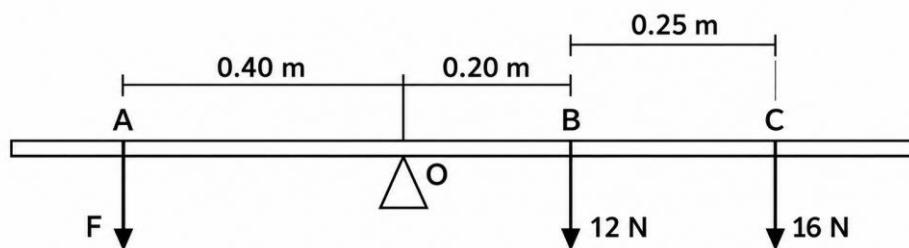
Answer / mark points: No. The force and its perpendicular distance from the pivot are unchanged, so Fd is unchanged. [1]

Teacher prompt: Unused length beyond the force application point does not increase the moment.



4 Balancing the tool tray

Figure 2 shows the downward loads on a rigid tray, supported at O. A load F acts at A; the other loads are 12 N at B and 16 N at C. The tray's own weight acts through O. The tray is initially horizontal and balanced. Ignore pivot friction.



A anticlockwise B clockwise C clockwise

Figure 2

4(a) Calculate the moment of the 12 N load at B about O and state its turning direction. **[2 marks]**

Answer / mark points: $M = 12 \times 0.20 = 2.4 \text{ N m}$. [1]

Clockwise. [1]

4(b) Use the dimensions in Figure 2 to calculate the moment of the 16 N load at C about O. **[2 marks]**

Answer / mark points: $OC = 0.20 + 0.25 = 0.45 \text{ m}$. [1]

$M = 16 \times 0.45 = 7.2 \text{ N m clockwise}$. [1]

Teacher prompt: BC is not the distance from the pivot. Add OB and BC.

4(c) Calculate the total clockwise moment of the two right-hand loads. **[1 mark]**

Answer / mark points: Total clockwise moment $= 2.4 + 7.2 = 9.6 \text{ N m}$. [1]

4(d) Calculate F , the load at A needed to keep the tray balanced. **[2 marks]**

Answer / mark points: For balance, $F \times 0.40 = 9.6$. [1]

$F = 9.6 / 0.40 = 24 \text{ N}$. [1]

Teacher prompt: Do not simply add 12 N and 16 N. Their distances differ from the distance of A.



4 Balancing the tool tray continued

4(e) Only the 12 N load is moved: its new distance is 0.30 m to the right of O. F remains 24 N at A. Use moments to predict the tray's initial turning direction when released from horizontal. **[2 marks]**

Answer / mark points: Clockwise total = $(12 \times 0.30) + 7.2 = 10.8 \text{ N m}$; anticlockwise = $24 \times 0.40 = 9.6 \text{ N m}$. [1 for the comparison]
It initially turns clockwise because the clockwise total is larger (resultant moment 1.2 N m clockwise). [1]

Teacher prompt: Predict the initial motion only; do not assume the same moments remain at every later angle.

4(f) Keep the 12 N load at its new position and the 16 N load at C. Calculate how far to the left of O the 24 N load must be moved to restore balance. **[2 marks]**

Answer / mark points: For balance, $24d = 10.8$. [1]
 $d = 10.8 / 24 = 0.45 \text{ m}$ left of O, 0.05 m farther out than A. [1]

4(g) Explain why the tray's own weight contributes no moment about O in these horizontal tests. **[1 mark]**

Answer / mark points: Its line of action passes through O, so its perpendicular distance and moment about O are zero. [1]

5 Testing the balance rule

A small horizontal rule balances on a pivot at its own centre of mass. One downward load is placed on each side. Ignore pivot friction. Table 1 gives separate test settings; find the right-hand distance needed for balance.

Table 1

Test	Left load / N	Left distance / m	Right load / N
P	6	0.20	4
Q	6	0.30	4
R	8	0.15	4

5(a) For test P in Table 1, calculate the right-hand distance needed for balance. **[1 mark]**

Answer / mark points: $4d = 6 \times 0.20$, so $d = 1.20 / 4 = 0.30 \text{ m}$. [1]

5(b) Calculate the right-hand distance for test Q and then for test R. **[2 marks]**

Answer / mark points: Q: $d = (6 \times 0.30) / 4 = 0.45 \text{ m}$. [1]
R: $d = (8 \times 0.15) / 4 = 0.30 \text{ m}$. [1]



5 Testing the balance rule continued

5(c) In test P, the pivot is at the 35 cm mark and the right-hand 4 N load acts at the 65 cm mark. A pupil uses 0.65 m in $M = Fd$. Calculate the correct right-hand moment and identify the distance error. **[2 marks]**

Answer / mark points: $d = (65 - 35) \text{ cm} = 30 \text{ cm} = 0.30 \text{ m}$, not 0.65 m. [1]
 $M = 4 \times 0.30 = 1.20 \text{ N m}$. The pupil measured from the end of the rule, not from the pivot. [1]

5(d) Describe a practical method to test whether total clockwise and anticlockwise moments are equal when a rule is balanced. Include the measurements, how you would obtain several results and how you would compare them. **[4 marks]**

Answer / mark points: First balance the unloaded rule horizontally on a pivot at its centre of mass, so its own weight has no moment. [1]
 Hang known weights on both sides; measure each perpendicular distance from the pivot to the vertical force's line of action. [1]
 Adjust a load's position until the rule rests horizontally without being held. Repeat with several different load and distance combinations. [1]
 Calculate each Fd , total the moments separately by direction and compare the totals for each balance. Repeat settings and judge agreement within measurement precision. [1]

Teacher prompt: Require a usable sequence and comparison, not four isolated words. Use small secured loads over a tray, keep feet clear and prevent the rule falling. Measuring from the ruler end is not acceptable.

5(e) For one horizontal balance, measured clockwise and anticlockwise moments are 1.20 N m and 1.24 N m. Each true value may be up to 0.05 N m above or below its measurement. Are the results consistent with equal moments? Use the possible ranges and explain what they do not prove. **[2 marks]**

Answer / mark points: Possible ranges are 1.15–1.25 N m and 1.19–1.29 N m; they overlap. [1]
 The results are consistent with equal moments within the stated measurement limits, but do not prove exact equality. [1]

Teacher prompt: A small numerical difference does not by itself disprove balance. Do not claim exact equality from rounded measurements.



6 Transmitting a turning effect with gears

Figure 3 shows a simple drive with fixed axes. Gear A is driven clockwise. The effective radii at the contact are supplied. For the calculation tests, the tangential contact-force magnitude is 50 N on each gear, perpendicular to its radius. Ignore frictional losses.

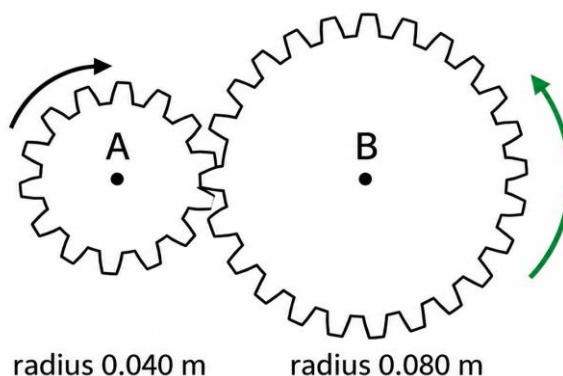


Figure 3

6(a) On Figure 3, draw a curved arrow to show the direction in which B turns. **[1 mark]**

Answer / mark points: B turns anticlockwise. [1] The green curved arrow shows this direction.

6(b) Explain how the driven gear A transmits a turning effect to B. **[1 mark]**

Answer / mark points: The meshing teeth exert a contact force on B away from its axis, producing a moment about B's axis. [1]

6(c) Using the stated 50 N contact force and A's effective radius, calculate the magnitude of the contact-force moment on A. **[1 mark]**

Answer / mark points: $M = Fd = 50 \times 0.040 = 2.0 \text{ N m}$. [1] This contact moment opposes A's driving moment.

6(d) Using the same force magnitude, calculate the contact-force moment that drives B. **[1 mark]**

Answer / mark points: $M = Fd = 50 \times 0.080 = 4.0 \text{ N m}$ anticlockwise. [1]

6(e) The two gears experience the same contact-force magnitude. Explain why the contact-force moment on B is larger than on A. **[2 marks]**

Answer / mark points: B has twice the effective perpendicular distance from its axis to the tangential contact force. [1]
With the same F , $M = Fd$ gives twice the moment on B (4.0 N m rather than 2.0 N m). [1]

Teacher prompt: Do not say the force doubles. The greater moment comes from the greater perpendicular distance.

6(f) A replacement output gear has an effective radius of 0.040 m. At the same 50 N contact force, can it overcome an opposing moment of 3.0 N m? Calculate and compare with the original B. **[2 marks]**

Answer / mark points: Replacement moment = $50 \times 0.040 = 2.0 \text{ N m}$, less than 3.0 N m, so it cannot overcome the resistance. [1]
Original B gives 4.0 N m, greater than 3.0 N m, so it can. [1]

Review and improve

A moment is a turning effect about a pivot. Use the perpendicular distance to the force's line of action, not the length of unused handle. Right-side downward loads turn clockwise; left-side downward loads turn anticlockwise. Balanced moments need not mean equal loads. For directly meshing gears, the turning direction reverses. Moment units are N m; do not report a moment in J, even though work has the same dimensions.

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk

