OCR A A Level Physics: Moments and equilibrium

35–40 minutes independent practice + 15–20 minutes review

Specification points covered

- 3.2.1(c) Understand weight of an object, W = mg.
- 3.2.1(d) Define and identify tension.
- 3.2.3(a) Define moment of a force; moment = F × x.
- 3.2.3(c) State and apply the principle of moments.
- 3.2.3(d) Define the centre of mass and centre of gravity.
- 3.2.3(e) Describe equilibrium of an object under the action of forces and torques.

Main scenario

A museum suspends a balanced kinetic display from two vertical support cables. Several objects hang from a uniform 4.00 m main beam. One hanging object is a second, shorter uniform beam carrying two samples. All cords and cables are light, the beams are rigid, and the complete display is stationary. Take g = 9.81 m s^{-2} throughout.

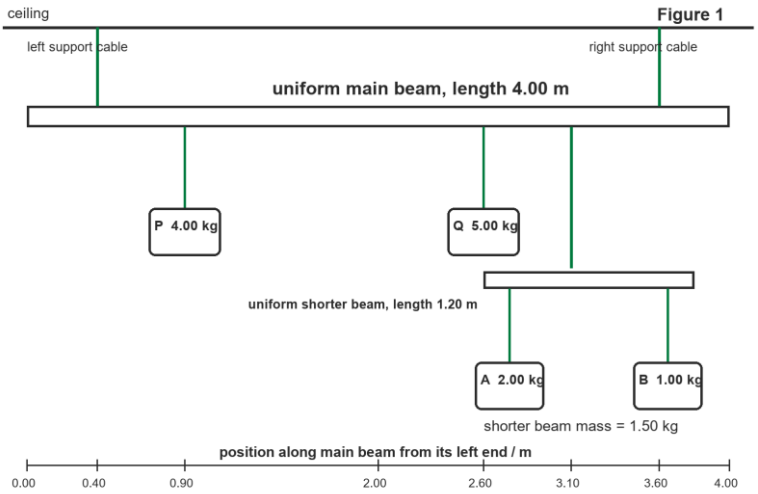


Figure 1

1. Define the moment of a force about a point. [1 mark]

2. Define tension. State the direction in which a tension force acts. [1 mark]

1. Definitions and equilibrium conditions

3. The complete display is in equilibrium. State the two conditions that must be satisfied for equilibrium. [2 marks]

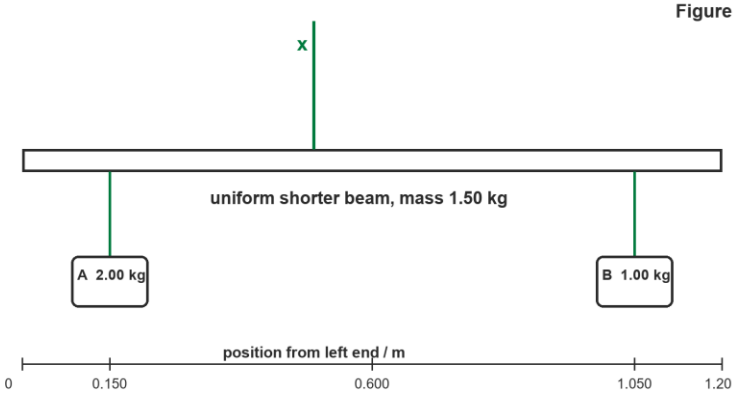
4. State the principle of moments using precise wording. [2 marks]

2. The shorter hanging beam

Shorter-beam data

Length = 1.20 m; mass of uniform beam = 1.50 kg; object A: 2.00 kg at 0.150 m; object B: 1.00 kg at 1.050 m. All positions are measured from the left end.

Figure 2



5. Treat the shorter beam and its two hanging objects as one system. On Figure 2 draw and label the four external forces acting on this system. [2 marks]

6. Calculate the tension T_s in the cord supporting the shorter beam system. [2 marks]

2. The shorter hanging beam continued

7. Take moments about the left end of the shorter beam. Calculate the attachment position x that keeps the shorter beam horizontal. [3 marks]

8. Explain why the cord exerts a downward force of the same magnitude on the main beam. [2 marks]

9. Object B is moved 0.200 m to the left while the supporting cord remains at its original position. State the direction in which the shorter beam initially rotates and explain your answer. [2 marks]

10. Calculate the new attachment position of the supporting cord that restores equilibrium after object B is moved. [2 marks]

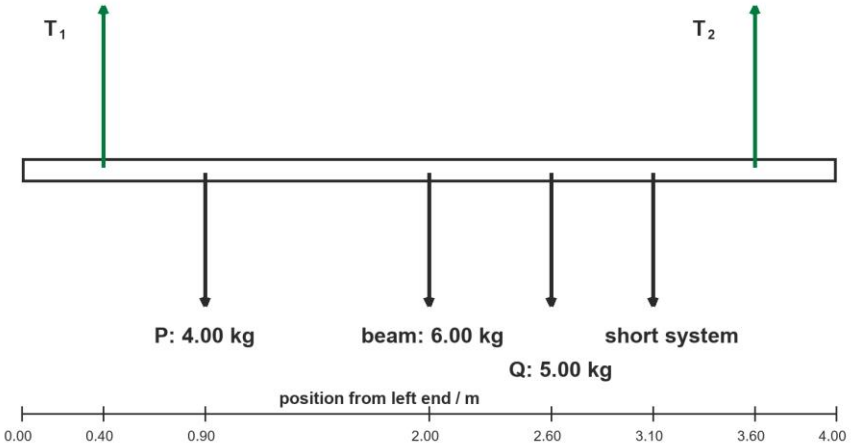
Check your language
Name the force or moment that changes. Then state whether the quantity increases, decreases or stays the same.

3. Support tensions in the main beam

Main-beam data

The uniform main beam has mass 6.00 kg. Support cables are at 0.40 m and 3.60 m. Object P has mass 4.00 kg at 0.90 m. Object Q has mass 5.00 kg at 2.60 m. The shorter system is attached at 3.10 m.

Figure 3



11. Calculate the weights of the uniform main beam, object P and object Q. State the position at which the weight of the uniform main beam acts. [2 marks]

12. Explain why taking moments about the left support removes T_1 from the moment equation. [1 mark]

13. Use the principle of moments about the left support to calculate the tension T_2 in the right support cable. [3 marks]

14. Use vertical force equilibrium to calculate the tension T_1 in the left support cable. [2 marks]

4. Explaining and changing equilibrium

15. The main beam is horizontal and in equilibrium, but T_1 and T_2 are not equal. Explain why this is possible. [2 marks]

16. A pupil states, 'The display is in equilibrium, so no forces act on it.' Explain why this statement is incorrect. [2 marks]

17. Object Q is moved from 2.60 m to 1.60 m from the left end of the main beam. Without calculation, state how T_1 and T_2 change. Explain your reasoning. [3 marks]

18. Object Q is returned to its original position. An extra object of mass 3.00 kg is hung 3.80 m from the left end. The maximum safe tension in the right support cable is 120 N. Determine whether the cable remains safe. [4 marks]

Review and improve

- □ I use perpendicular distance to a line of action.
- □ I state both equilibrium conditions precisely.
- □ I can choose a pivot that removes an unknown force.
- □ I explain support-tension changes using both force and moment equilibrium.