IG.P4 Hooke's Law, Moments and Centre of Mass

EDEXCEL 4PH1 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 State Hooke's law for a spring, as used in statics and elastic deformation experiments.

(Total for Question 1 is 2 marks)

---

2 State the SI unit of the spring constant k in the equation F = k e for a spring in statics.

(Total for Question 2 is 1 mark)

---

3 A student hangs a mass so that a spring extends by 0.080 m when the applied force is 2.4 N. Calculate the spring constant k for this spring using F = k e.

(Total for Question 3 is 3 marks)

---

4 A force-extension experiment gives the following measurements for a particular spring: 0.50 N produces 0.020 m extension, 1.00 N produces 0.040 m, 1.50 N produces 0.060 m. From these data, determine the spring constant k and state whether the spring is obeying Hooke's law in this range.

(Total for Question 4 is 3 marks)

5 Define the limit of proportionality for a spring, as used when interpreting a force-extension graph.

(Total for Question 5 is 2 marks)

---

6 A spring is stretched by 0.120 m by a force of 24 N. Calculate the spring constant k and then calculate the extension that would result from a 30 N force, assuming the spring remains within its limit of proportionality.

(Total for Question 6 is 2 marks)

---

7 A mechanic applies a force of 40 N to a wrench at a perpendicular distance of 0.25 m from the pivot. Calculate the turning effect (moment) produced about the pivot.

(Total for Question 7 is 2 marks)

---

8 A uniform metre ruler is balanced on a pivot at the 40 cm mark. A 0.50 kg mass is hung at the 10 cm mark. Calculate the magnitude of the clockwise moment caused by the mass about the pivot. Use $g = 9.8\ N\ kg^{-1}$ and treat the mass weight as the force.

(Total for Question 8 is 3 marks)

---

9 State the principle of moments for an object in equilibrium on a pivot, as used to solve statics problems.

(Total for Question 9 is 2 marks)

10 A beam is balanced on a pivot. A 5.0 N force is applied 0.40 m to the left of the pivot producing an anticlockwise moment. To balance, a second force is applied 0.20 m to the right of the pivot. Calculate the magnitude of the second force required using the principle of moments.

(Total for Question 10 is 3 marks)

---

11 A 2.0 N weight is placed 0.30 m to the left of a pivot and a 3.0 N weight is placed 0.20 m to the right of the pivot. Calculate the resultant moment about the pivot and state whether the net turning is clockwise or anticlockwise.

(Total for Question 11 is 2 marks)

---

12 On a force-extension graph for a spring, explain briefly what is shown by a straight line through the origin and what is shown by the curve that starts beyond the straight region, referring to elastic and plastic behaviour.

(Total for Question 12 is 2 marks)

---

13 A rectangular block stands upright on a table. Its centre of mass lies vertically above the centre of its base. Explain why the block is stable. In your answer mention torque and base area.

(Total for Question 13 is 4 marks)

14 A tall narrow container and a short wide container have the same mass distribution height such that the tall container has a higher centre of mass. State which container is more stable and give one reason referring to the centre of mass height.

(Total for Question 14 is 2 marks)

---

15 A uniform lamina of length 60 cm is supported at its 20 cm mark. A 6.0 N weight is placed at the 0 cm end and a 4.0 N weight at the 60 cm end. Calculate whether the lamina will balance about the support, showing the moments about the support and the resultant.

(Total for Question 15 is 3 marks)

Mark scheme · IG.P4 Hooke's Law, Moments and Centre of Mass

Question 1

- **B1** states that extension is directly proportional to applied force (within limit of proportionality)
- **B1** gives the equation F = k e or equivalent, with F force, k spring constant and e extension
- **Answer: Extension is directly proportional to force (within the limit of proportionality); F = k e**

Question 2

- **B1** N m^{-1} or N per m
- **Answer: N m^{-1}**

Question 3

- **M1** quotes the equation F = k e or rearranges to k = F / e
- **M1** substitutes values k = 2.4 / 0.080
- **A1** gives k = 30 N m^{-1} cao
- **Answer: k = 30 N m^{-1}**

Question 4

- **M1** uses k = F / e for one data pair or recognises constant ratio across pairs
- **A1** calculates k = 0.50 / 0.020 = 25 N m^{-1} (or equivalent from another pair)
- **B1** states that k is constant and therefore the spring obeys Hooke's law in this range
- **Answer: k = 25 N m^{-1}; yes, Hooke's law is obeyed because F/e is constant**

Question 5

- **B1** identifies the limit of proportionality as the point beyond which extension is no longer directly proportional to force
- **B1** may state it is the point on a force-extension graph where the line stops being straight (becomes curved)
- **Answer: The limit of proportionality is the point beyond which extension is not directly proportional to force; on a graph it is where the straight line starts to curve**

Question 6

- **M1** uses k = F / e = 24 / 0.120
- **A1** gives k = 200 N m^{-1} and then e = F / k = 30 / 200 = 0.150 m cao
- **Answer: k = 200 N m^{-1}; extension at 30 N = 0.150 m**

Question 7

- **M1** uses moment = force x perpendicular distance
- **A1** gives moment = 40 x 0.25 = 10 N m cao
- **Answer: 10 N m**

Question 8

- **M1** calculates weight as force = mass x g = 0.50 x 9.8
- **M1** calculates perpendicular distance from pivot = 40 cm - 10 cm = 30 cm = 0.30 m and sets moment = force x distance
- **A1** computes moment = (0.50 x 9.8) x 0.30 = 1.47 N m cao
- **Answer: 1.47 N m (clockwise)**

Question 9

- **B1** states that for equilibrium the sum of clockwise moments about a pivot equals the sum of anticlockwise moments
- **B1** may mention moments measured about the same pivot
- **Answer: Sum of clockwise moments about a pivot = sum of anticlockwise moments about that pivot (for equilibrium)**

Question 10

- **M1** sets up equilibrium: sum clockwise = sum anticlockwise, so F2 x 0.20 = 5.0 x 0.40
- **M1** rearranges to F2 = (5.0 x 0.40) / 0.20
- **A1** gives F2 = 10 N cao
- **Answer: 10 N**

Question 11

- **M1** calculates left moment = 2.0 x 0.30 = 0.60 N m and right moment = 3.0 x 0.20 = 0.60 N m
- **A1** gives resultant moment = 0.00 N m and states no net turning (balanced) cao
- **Answer: Resultant moment = 0.00 N m; balanced, no net turning**

Question 12

- **B1** straight line through origin shows proportional behaviour, obeying Hooke's law, elastic region where extension returns when force removed
- **B1** curve beyond straight region shows limit of proportionality and plastic behaviour where permanent extension occurs after force removed
- **Answer: Straight line through origin indicates Hooke's law and elastic behaviour; the curved region beyond shows the limit of proportionality and plastic behaviour with permanent extension**

Question 13

- **B1** states that stability depends on whether the vertical line from the centre of mass falls within the base area
- **B1** states that if it falls within the base, any small tilt produces a restoring moment that returns the block to upright
- **B1** refers to torque or turning effect, that weight acting through the centre of mass produces a moment about the edge that tends to reduce the tilt
- **B1** may state that a large base area and low centre of mass increase the restoring moment and so increase stability
- **Answer: The block is stable because the vertical line from its centre of mass falls inside the base so any small tilt produces a restoring moment. The weight acting through the centre of mass creates a torque about the edge that returns the block upright. A large base area and a low centre of mass increase this restoring moment and enhance stability.**

Question 14

- **B1** states the short wide container is more stable
- **B1** gives reason: lower centre of mass gives smaller tipping moment so harder to tip
- **Answer: The short wide container is more stable because its centre of mass is lower, producing a smaller tipping moment for the same tilt**

Question 15

- **M1** calculates moments about support: left moment = 6.0 x 0.20 = 1.20 N m; right moment = 4.0 x 0.40 = 1.60 N m
- **M1** finds resultant moment = 1.60 - 1.20 = 0.40 N m and identifies sense (clockwise)
- **A1** concludes lamina will not balance and will rotate clockwise with resultant 0.40 N m
- **Answer: Right moment 1.60 N m, left moment 1.20 N m, resultant 0.40 N m clockwise, so it will not balance**