JURONG PIONEER JUNIOR COLLEGE
9478 H2 PHYSICS

FORCES AND MOMENTS TUTORIAL

Take $g = 9.81\ \text{m s}^{-2}$

Self-Check Questions

S1 State Hooke's law.

S2 Sketch the graph of force against extension for a spring that obeys Hooke's law.

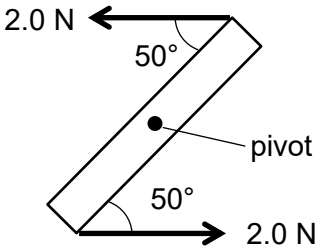
S3 Define the moment of a force and the torque of a couple.

S4 State the conditions for equilibrium of a body.

Self-Practice Questions

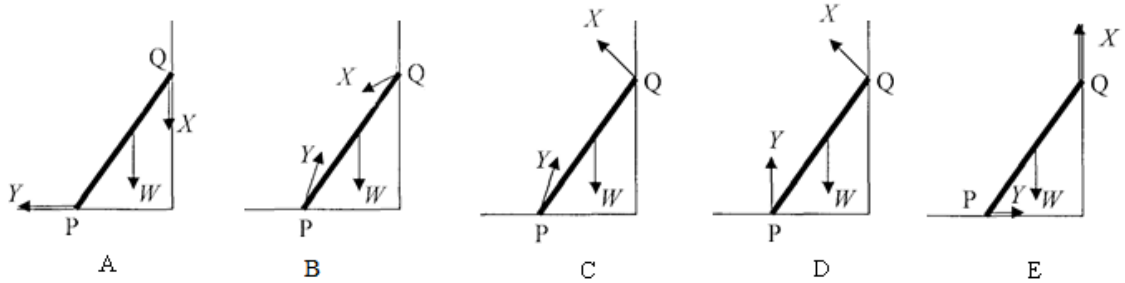
P1 A spring with an unstretched length of 50 mm stretches to a length of 70 mm when the tension in the spring is 10 N. Assuming that the limit of proportionality is not exceeded, determine the length of the spring when the tension in the spring is 20 N.

P2 A ruler of length 0.30 m is pivoted at its centre. Equal and opposite forces of magnitude 2.0 N are applied to the ends of the ruler, creating a couple as shown.

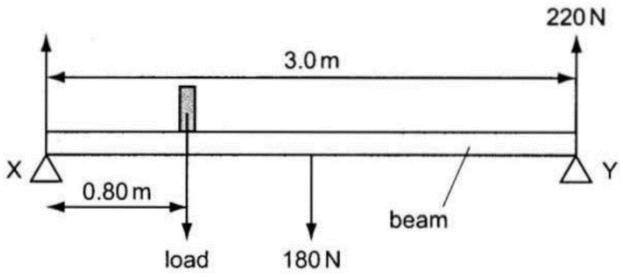


Calculate the magnitude of the torque of the couple on the ruler when it is in the position shown.

P3 [N1984/2/1]
A ladder PQ, resting on a rough floor and leaning against a rough wall, is on the point of slipping. It is of weight W and the contact forces exerted on the ladder by the wall and the floor are X and Y respectively. Which one of the following diagrams correctly shows the directions of these forces?



P4 [N2010/1/9 modified]
A uniform beam in a roof structure has a weight of 180 N. It is supported in two places X and Y, a distance 3.0 m apart. A load is placed on the beam a distance of 0.80 m from X. The support provided by Y is 220 N.



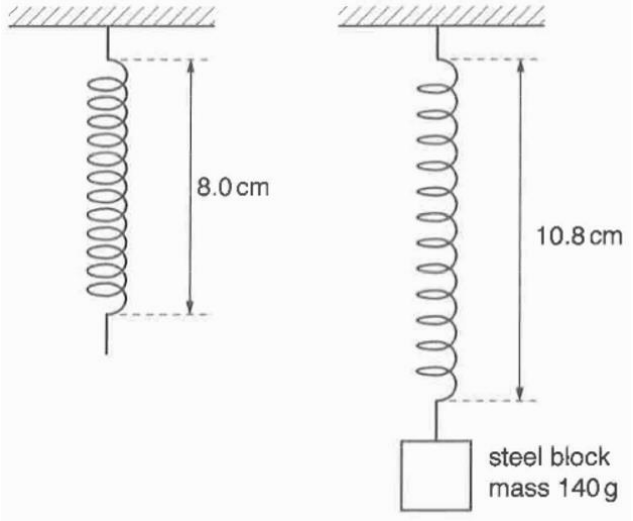
Calculate the value of the load.

Discussion Questions

Types of force and Hooke's law

1 For a car, motion is impossible without friction.
(a) Discuss what is meant by friction and the direction in which it acts on the car.
(b) Suggest another example where friction is useful.
(c) Describe a situation in which motion is produced without friction being required.

2 [N2017/P2/Q1 (part)]
A spring has an unstretched length of 8.0 cm. The top of the spring is attached to a fixed point.
A steel block of mass 140 g is suspended from the lower end so that the length of the spring increases to 10.8 cm, as shown in the figure below.



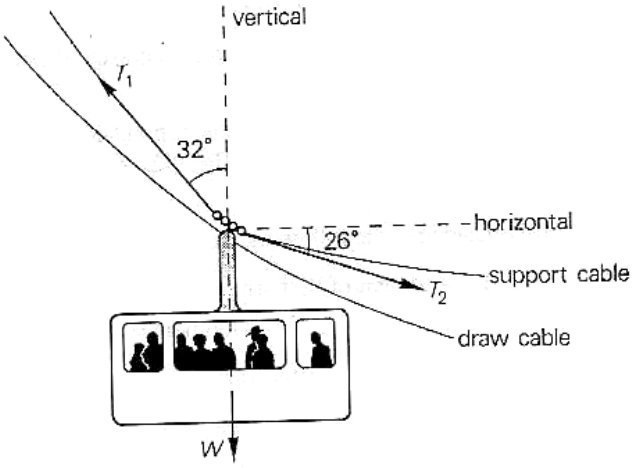
(a) Calculate the force constant of the spring. [2]

(b) (i) The percentage uncertainty in the mass is ±1.0 %. The actual uncertainty in each measurement of the length of the spring is ±1 mm.
Calculate the percentage uncertainty in the force constant. [2]
(ii) Use your answers in **(a)** and **(b)(i)** to determine the value of the force constant, with its actual uncertainty, to an appropriate number of significant figures. [1]

Moment and torque, translational and rotational equilibrium

3 [N1992/III/3 (part)]

A cable car travels along a fixed support cable and is pulled along this cable by a moving draw cable.



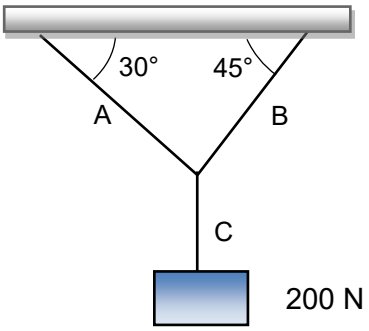
For the situation shown, where the cable car can be considered to be stationary and the draw cable exerts negligible force on it, the weight, W of the cable car and the passengers is 8.0×10^4 N.

(a) Sketch a vector triangle to show the weight, W of the cable car and passengers and T_1 and T_2, the tensions in the two cables.

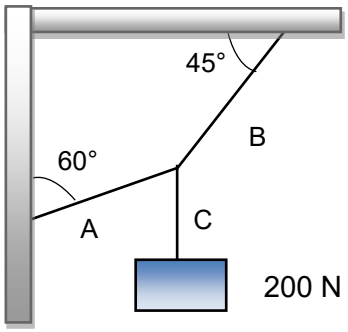
(b) Find the magnitude of T_1.

4 Determine the tensions in each of the strings.

(a)

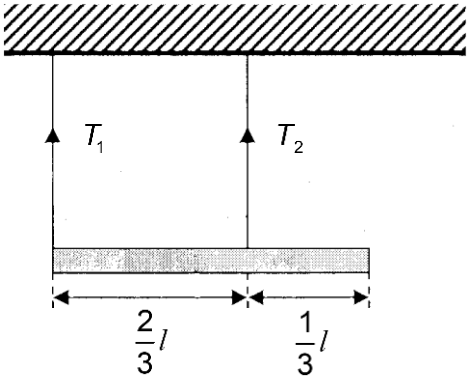


(b)



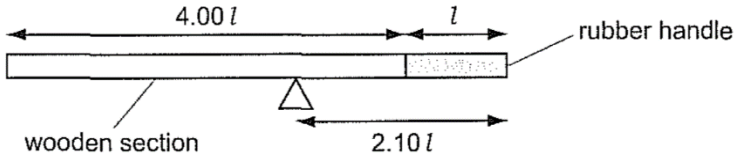
5 A heavy uniform beam of length l is supported by two vertical cords as shown.

Determine the ratio $\frac{T_1}{T_2}$.



6 [N2008/1/8]

A uniform rod has a wooden section and a solid rubber handle, as shown.

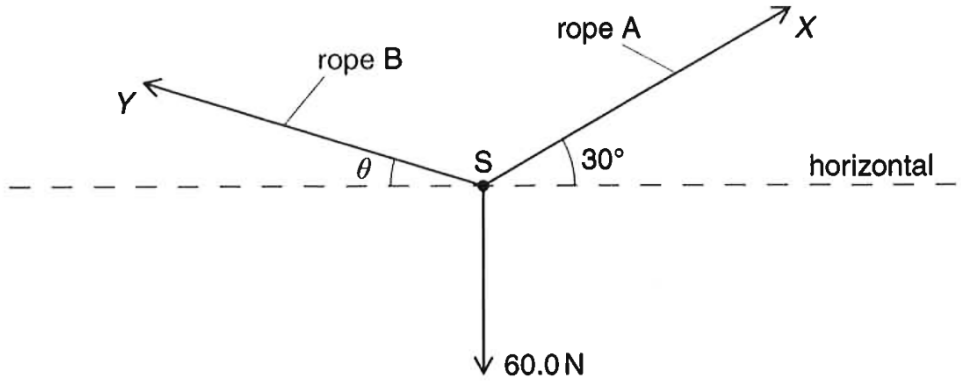


The length of the handle is l and the length of the wooden section is 4.00 l.
The rod balances a distance 2.10 l from the rubber end.

Calculate the ratio of density of rubber to that of wood.

7 [N2014/2/1]

An object S of weight 60.0 N is supported by two ropes A and B, as shown in the figure below.



Rope A is at 30° to the horizontal and exerts force X on S. Rope B is at an angle θ to the horizontal and exerts force Y on S.

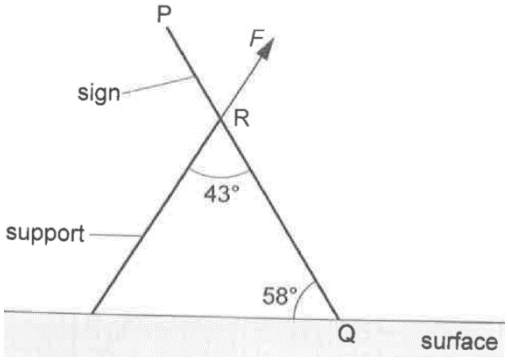
The magnitude of force X is varied from 0 to 200 N. Rope A is always kept at 30° to the horizontal. The force Y is varied in magnitude and direction to keep S in equilibrium.

(a) Determine the magnitude of force Y and angle θ for the magnitude of force X equal to
(i) zero, [2]
(ii) 200 N. [3]

(b) By reference to the figure, explain why the rope B cannot be parallel to the weight of S no matter how large the magnitude of X. [2]

8 [N2021/2/3]

A sign PQ and its support stand are in equilibrium on a horizontal surface, as shown in the figure below.



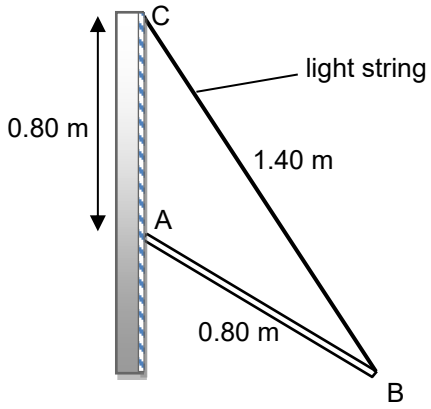
The sign is uniform and has a mass of 2.3 kg. The sign is at an angle of 58° to the surface. The support joins to the sign at point R where PR = PQ/3. The support is at an angle of 43° to the sign and exerts a force *F* on the sign. Force *F* is parallel to the support.

(a) By taking moments about point Q, determine the force *F*. [3]

(b) Explain why the force acting on the sign at Q is not vertical. [2]

Challenging Question

9 A uniform bar AB of length 0.80 m and mass 10.0 kg rests with the end A against a rough wall. A light string of length 1.40 m connects B to a point C on the wall 0.80 m above A.



Determine the tension in the string and the magnitude of friction between the bar and the wall if the bar is about to slip.

Answers:

P1	0.090 m	**2**	**(a)** 49.1 N m^{-1} **(b)(i)** 8.1% **(ii)** (49 ± 4) N m^{-1}	**6**	2.25
P2	0.46 N m	**3**	1.36 × 10^5 N	**7**	**(a)(i)** 60.0 N, 90° **(a)(ii)** 178 N, −13.0°
P3	C	**4**	**(a)** A: 146 N, B: 179 N, C: 200 N **(b)** A: 546 N, B: 669 N, C: 200 N	**8**	**(a)** 13.1 N
P4	490 N	**5**	0.33	**9**	T = 85.8 N, f = 23.0 N