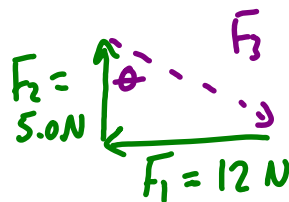


1. State the condition for translational equilibrium.

- A. $\Sigma F = 0$
- B. $\Sigma F \neq 0$
- C. $\Sigma \tau = 0$
- D. $\Sigma \tau \neq 0$

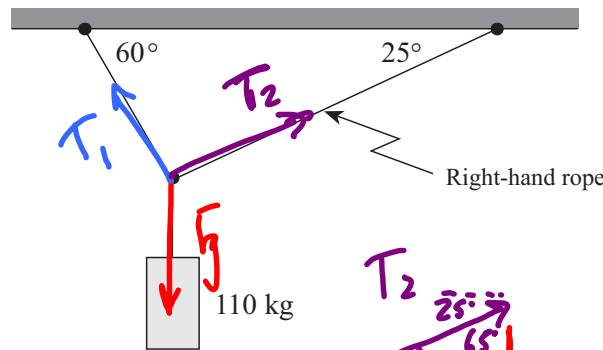
2. Two forces, 12 N west and 5.0 N north, act on an object. What is the direction of a third force that would produce static equilibrium?

- A. 23° south of east
- B. 23° north of west
- C. 67° south of east
- D. 67° north of west



$$\begin{aligned} \theta &= \tan^{-1}\left(\frac{12}{5.0}\right) \\ &= 67^\circ \text{ E of S} \\ &= 23^\circ \text{ S of E} \end{aligned}$$

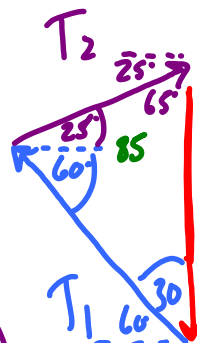
3. A 110 kg object is supported by two ropes attached to the ceiling. What is the tension T in the right-hand rope?



- A. 460 N
- B. 540 N
- C. 930 N
- D. 1 300 N

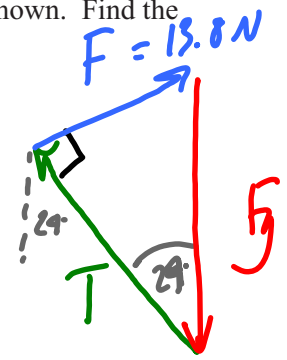
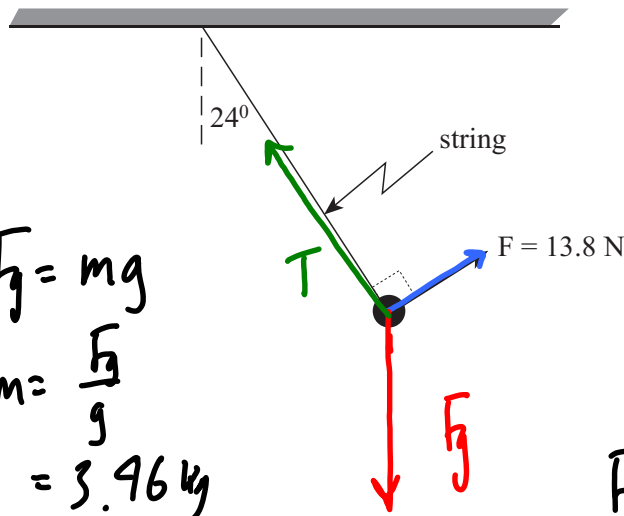
$$\frac{\sin 30}{T_2} = \frac{\sin 85}{1078 \text{ N}}$$

$$\begin{aligned} T_2 &= 1078 \left(\frac{\sin 30}{\sin 85} \right) \\ &= 541 \text{ N} \end{aligned}$$



$$F_g = mg = 1078 \text{ N}$$

4. A mass suspended by a string is held 24° from vertical by a force of 13.8 N as shown. Find the mass.



- A. 0.57 kg
 B. 1.5 kg
 C. 3.2 kg
 D. 3.5 kg

$$F_g = mg$$

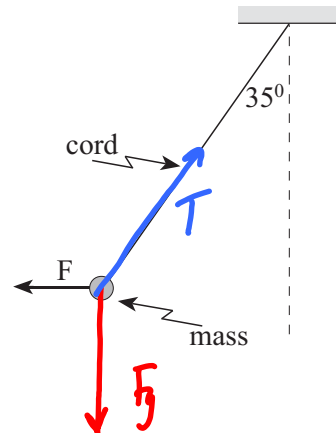
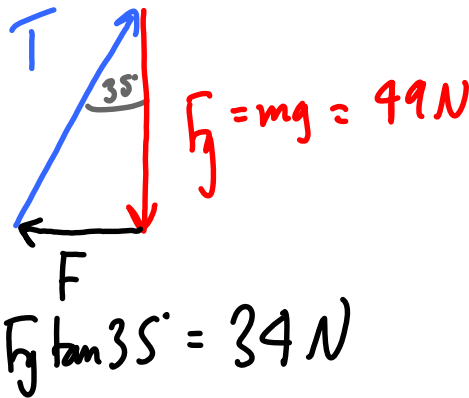
$$m = \frac{F_g}{g}$$

$$= 3.46\text{ kg}$$

$$\sin 24^\circ = \frac{F_g}{F}$$

$$F_g = \frac{F}{\sin 24^\circ} = 33.93\text{ N}$$

5. A mass of 5.0 kg is suspended from a cord as shown in the diagram below. What horizontal force F is necessary to hold the mass in the position shown?



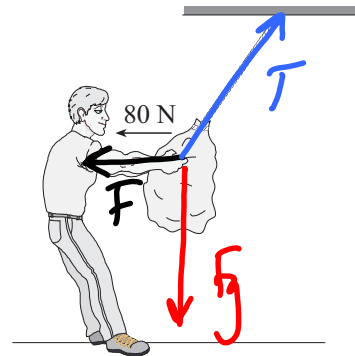
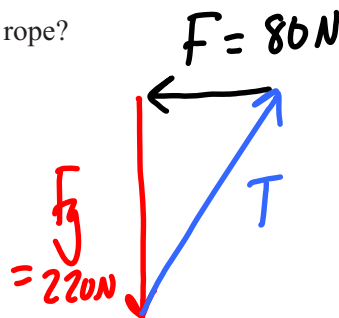
- A. 28 N
 B. 34 N
 C. 40 N
 D. 70 N

$$F = F_g \tan 35^\circ = 34\text{ N}$$

6. A 220 N bag of potatoes is suspended from a rope as shown in the diagram. A person pulls horizontally on the bag with a force of 80 N .

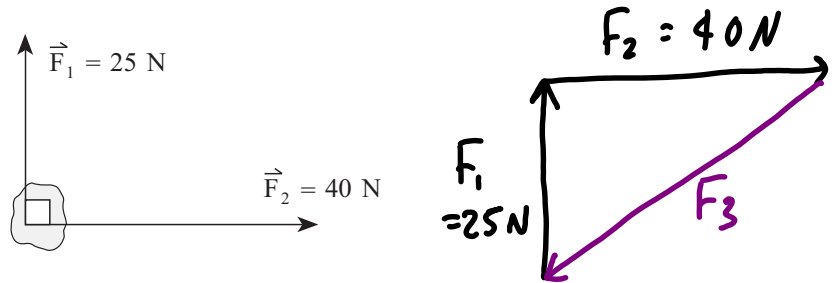
What is the tension in the rope?

- A. $1.4 \times 10^2\text{ N}$
 B. $2.2 \times 10^2\text{ N}$
 C. $2.3 \times 10^2\text{ N}$
 D. $3.0 \times 10^2\text{ N}$



$$T = \sqrt{220^2 + 80^2} = 230\text{ N}$$

7. Two forces act on an object as shown. Find the magnitude of the third force required to achieve translational equilibrium.



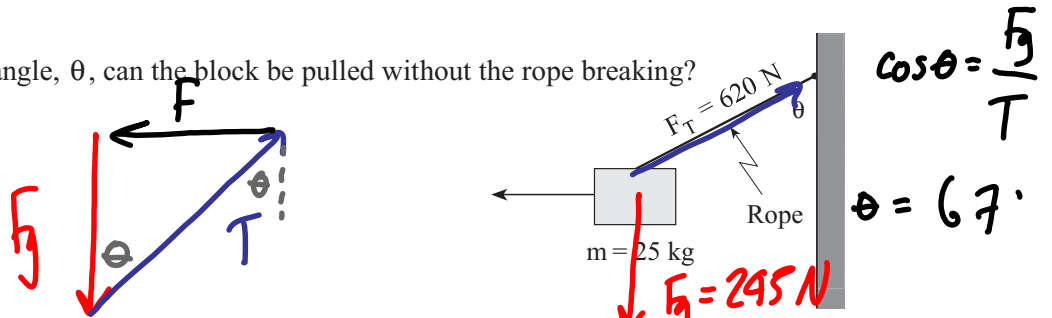
- A. 15 N
 B. 33 N
 C. 47 N
 D. 65 N

$$F_3 = \sqrt{F_1^2 + F_2^2} = 47.2 \text{ N}$$

8. A 25 kg block is pulled by a horizontal force. The supporting rope can withstand a maximum tension force of 620 N.

To what maximum angle, θ , can the block be pulled without the rope breaking?

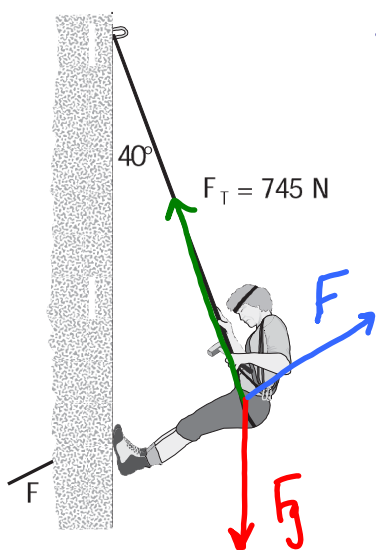
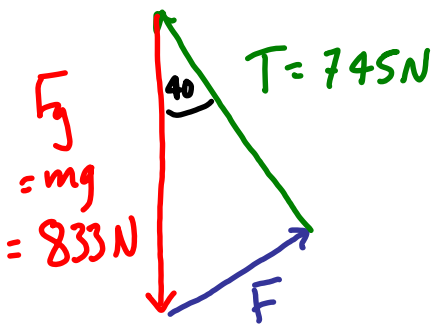
- A. 22°
 B. 23°
 C. 67°
 D. 88°



$$\cos \theta = \frac{F_g}{T}$$

$$\theta = 67^\circ$$

9. An 85.0 kg mountaineer remains in equilibrium while climbing a vertical cliff. The tension force in the supporting rope is 745 N.



$$F^2 = F_g^2 + T^2 - 2F_g T \cos 40$$

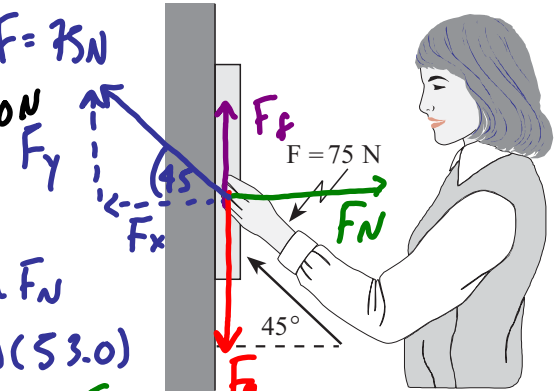
$$F = 546 \text{ N}$$

Find the magnitude of the reaction force, F , which the cliff exerts on the mountaineer's feet.

- A. 88.0 N
 B. 373 N
 C. 479 N
 D. 546 N

10. An artist must push with a minimum force of 75 N at an angle of 45° to a picture to hold it in equilibrium. The coefficient of friction between the wall and the picture frame is 0.30. What is the mass of the picture?

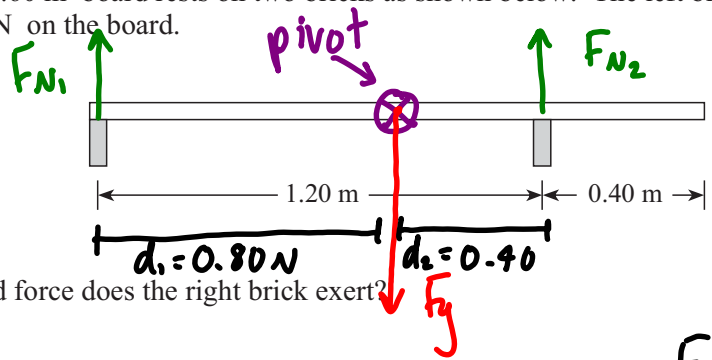
$$\begin{aligned} \sum F_x &= F_N - F_x = 0 \\ F_x &= F_N = 75 \cos 45 = 53.0 \text{ N} \\ \sum F_y &= F_y + F_f - F_g = 0 \\ F_g &= F_y + F_f = F_y + \mu F_N \\ &= 75 \sin 45 + (0.30)(53.0) \\ &= 68.9 \text{ N} \end{aligned}$$



- A. 1.6 kg
 B. 2.3 kg
 C. 3.8 kg
 (D) 7.0 kg

$$m = \frac{F_g}{g} = 7.0 \text{ kg}$$

11. A uniform 1.60 m board rests on two bricks as shown below. The left brick exerts an upward force of 12 N on the board.

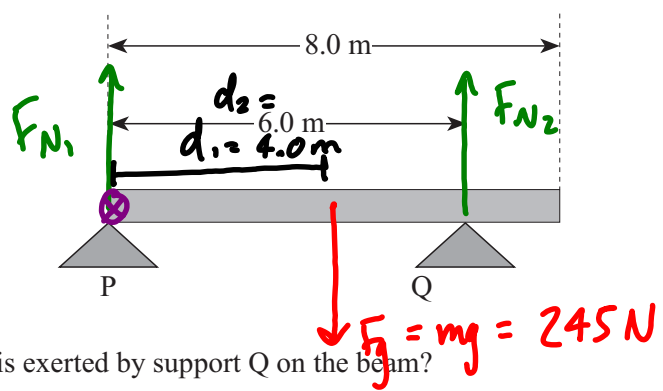


What upward force does the right brick exert?

- A. 3.0 N
 B. 12 N
 (C) 24 N
 D. 36 N

$$\begin{aligned} \tau_c &= \tau_{cc} \\ F_{N1} d_1 &= F_{N2} d_2 \\ F_{N2} &= \frac{F_{N1} d_1}{d_2} = \frac{(12 \text{ N})(0.80 \text{ m})}{(0.40 \text{ m})} \\ &= 24 \text{ N} \end{aligned}$$

12. A uniform beam of mass 25 kg rests on supports P and Q, as shown in the diagram below.



What force is exerted by support Q on the beam?

- A. $1.2 \times 10^2 \text{ N}$
 (B) $1.6 \times 10^2 \text{ N}$
 C. $3.3 \times 10^2 \text{ N}$
 D. $4.9 \times 10^2 \text{ N}$

$$\begin{aligned} \tau_c &= \tau_{cc} \\ F_g d_1 &= F_{N2} d_2 \\ F_{N2} &= \frac{F_g d_1}{d_2} \\ &= \frac{(245 \text{ N})(4.0 \text{ m})}{(6.0 \text{ m})} \\ &= 163 \text{ N} \end{aligned}$$

13. What are the units of torque?

- A. $N \times m$
- B. N/m
- C. $N \times s$
- D. N/s

$$\tau = F \cdot d$$
$$N \cdot m$$

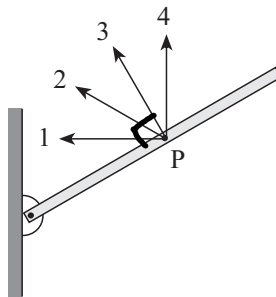
14. A body is in static equilibrium when

- A. $\Sigma \tau = 0$ only.
- B. $\Sigma F = 0$ only.
- C. $\Sigma F = 0$ and $\Sigma \tau = 0$.
- D. $\Sigma F = 0$ and $\Sigma \tau \neq 0$.

15. A body is in rotational equilibrium when

- A. $\Sigma \tau = 0$
- B. $\Sigma F = 0$
- C. $\Sigma p = 0$
- D. $\Sigma E_k = 0$

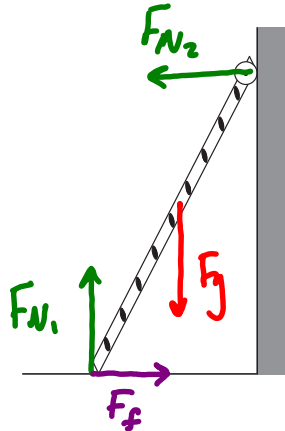
16. In which direction should a force act at point P to hold the boom in equilibrium so that the force will be a minimum?



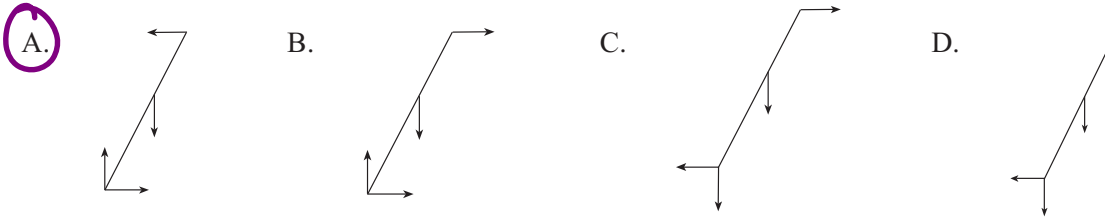
since $\tau = Fd \sin \theta$
F is a min
when $\theta = 90^\circ$

- A. 1
- B. 2
- C. 3
- D. 4

17. A uniform ladder leans against a frictionless wall as shown.

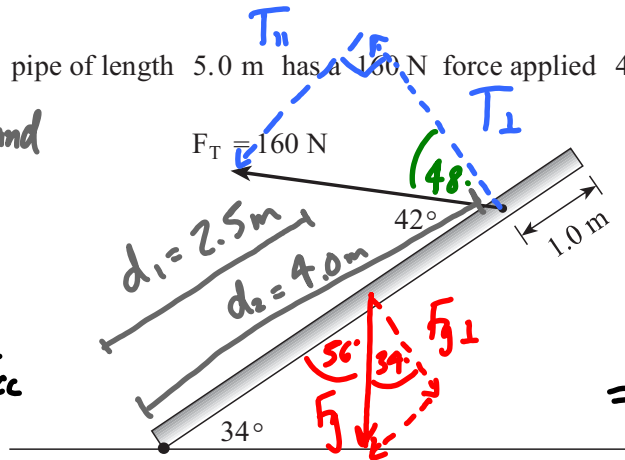


Which of the following diagrams best shows the forces acting on the ladder?



18. A uniform 15 kg pipe of length 5.0 m has a 160 N force applied 4.0 m from its lower end as shown.

Let C = positive and CC = negative
 $\tau_c \neq \tau_{cc}$
 $\sum \tau = \tau_c - \tau_{cc}$

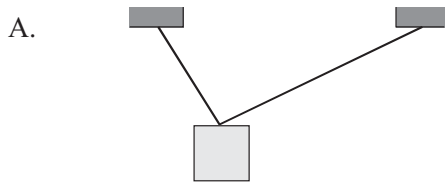


$$\begin{aligned} \sum \tau &= F_{g2} d_1 - T_{\perp} d_2 \\ m g \cos 39^{\circ} \cdot d_1 - T \cos 48^{\circ} \cdot d_2 \\ &= -123 \text{ N}\cdot\text{m} \\ &= 123 \text{ N}\cdot\text{m} \text{ counter-clockwise} \end{aligned}$$

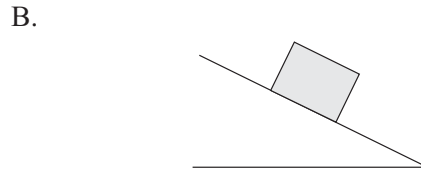
Using the point where the pipe touches the ground as a pivot, calculate the sum of the torques acting on the pipe.

- A. 180 N·m in a clockwise direction.
- B. 270 N·m in a clockwise direction.
- C. 120 N·m in a counter-clockwise direction.
- D. 270 N·m in a counter-clockwise direction.

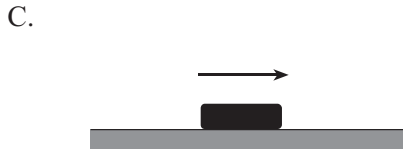
19. Which of the four problems shown requires the application of torque?



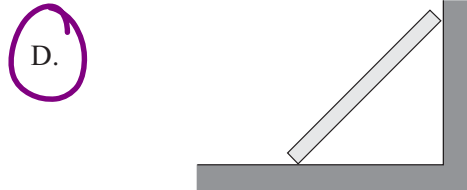
What is the tension in the supporting cables?



What is the friction force acting on the block?

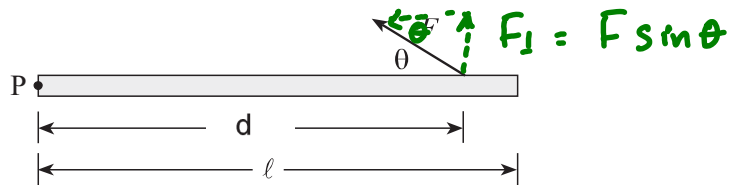


What is the acceleration of the puck?



What force does the wall exert on the board?

20. A force F is applied to a uniform horizontal beam as shown in the diagram below.

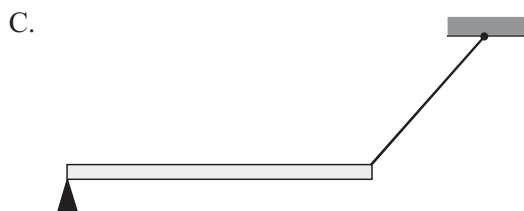
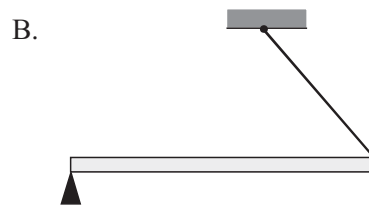
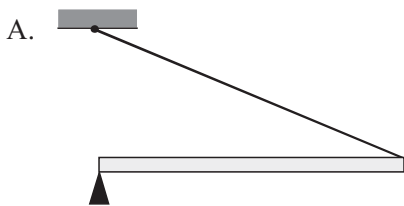


Which of the following is a correct expression for the torque on the beam about pivot point P due to this force?

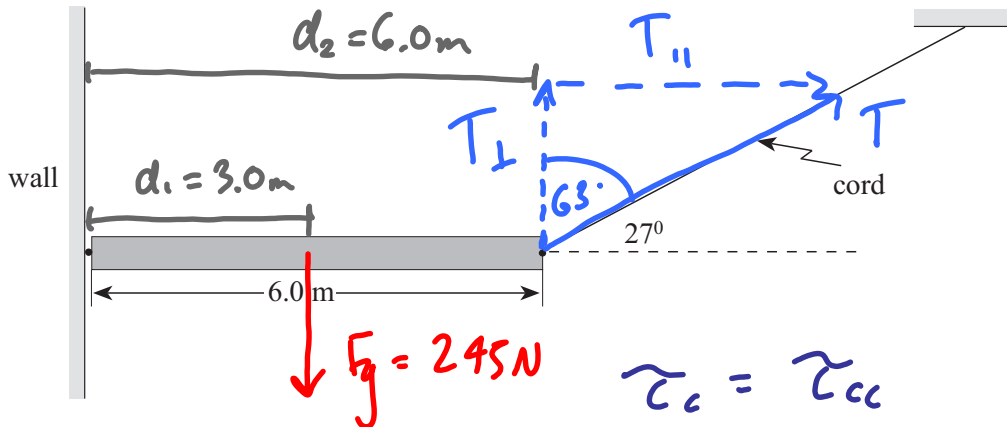
- A. $F \sin d$
- B. $F \sin d/l$
- C. $F \cos d$
- D. $F \cos d/l$

$$\tau = F \sin \theta \cdot d$$

21. A beam is to be kept horizontal by a cord. In which of the four situations shown below will the tension in the cord be least?



22. A uniform 25 kg bar, 6.0 m long, is suspended by a cord as shown.



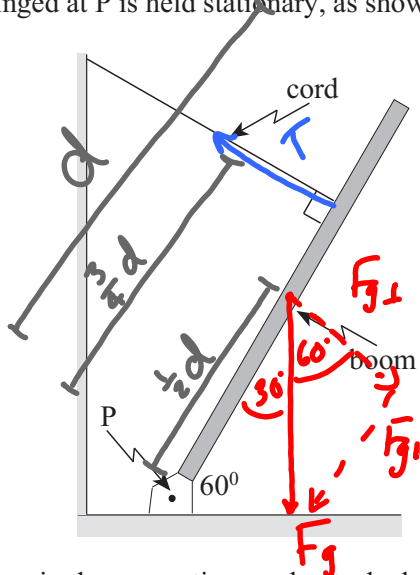
What is the tension in the cord?

- A. 1.2×10^2 N
- B. 2.7×10^2 N
- C. 3.7×10^2 N
- D. 5.4×10^2 N

$$T = \frac{T_{\perp}}{\cos 63^{\circ}} = 270 \text{ N}$$

$$\begin{aligned} \tau_c &= \tau_{cc} \\ F_g d_1 &= T_{\perp} d_2 \\ T_{\perp} &= \frac{F_g \cdot d_1}{d_2} = \frac{(245 \text{ N})(3.0 \text{ m})}{6.0 \text{ m}} \\ &= 122.5 \text{ N} \end{aligned}$$

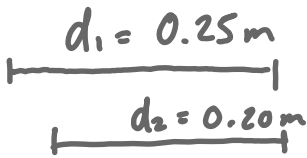
23. A boom hinged at P is held stationary, as shown in the diagram below.



$$\begin{aligned} \tau_c &= \tau_{cc} \\ F_{g\perp} \left(\frac{1}{2} d\right) &= T \left(\frac{3}{4} d\right) \\ \frac{1}{2} F_{g\perp} &= \frac{3}{4} T \\ F_{g\perp} &= \frac{3}{2} T = 1080 \text{ N} \\ F_g &= \frac{F_{g\perp}}{\cos 60} = \boxed{2160 \text{ N}} \end{aligned}$$

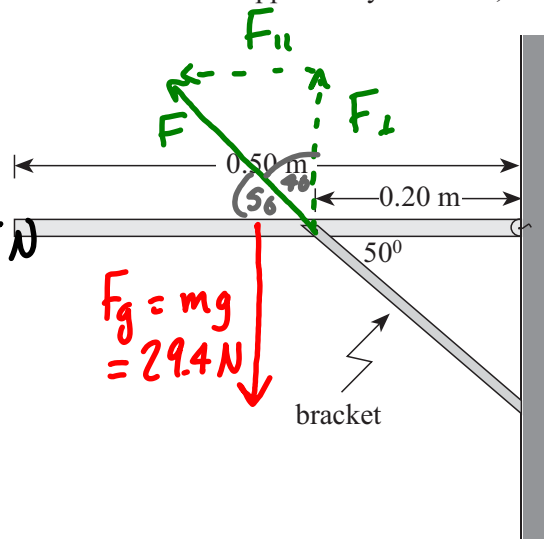
If the tension in the supporting cord, attached three-quarters of the way along the boom from P, is 720 N, what is the weight of the boom?

- A. 720 N
- B. 1 080 N
- C. 1 440 N
- D. 2 160 N



24. A uniform 3.0 kg shelf of width 0.50 m is supported by a bracket, as shown in the diagram below.

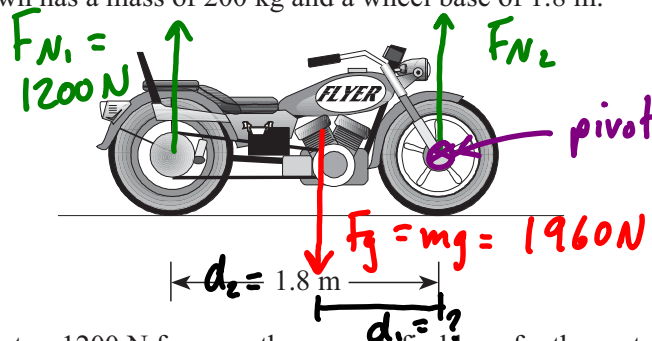
$$\begin{aligned} \tau_c &= \tau_{cc} \\ F_{\perp} d_2 &= F_g d_1 \\ F_{\perp} &= \frac{F_g d_1}{d_2} = 36.75 \text{ N} \\ F &= \frac{F_{\perp}}{\cos 40^\circ} \\ &= \underline{48.0 \text{ N}} \end{aligned}$$



What force does the bracket exert on the shelf?

- A. 7.4 N
- B. 38 N
- C. 48 N
- D. 57 N

25. The motorcycle shown has a mass of 200 kg and a wheel base of 1.8 m.

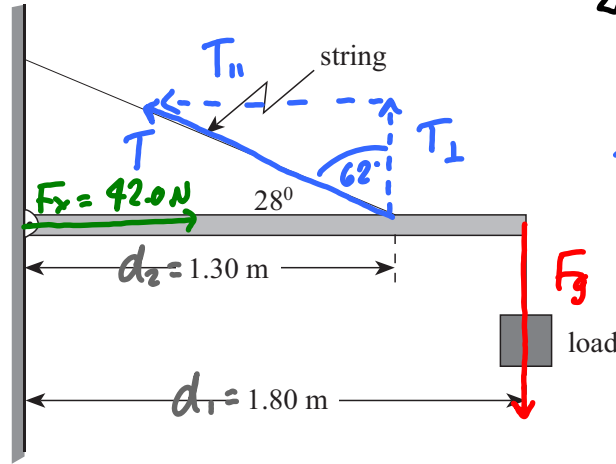


If the rear wheel exerts a 1200 N force on the ground, find how far the motorcycle's centre of gravity is located from the front wheel.

- A. 0.70 m
- B. 0.90 m
- C. 1.1 m
- D. 1.2 m

$$\begin{aligned} \tau_c &= \tau_{cc} \\ F_{N1} d_2 &= F_g d_1 \\ d_1 &= \frac{F_{N1} d_2}{F_g} = \frac{(1200 \text{ N})(1.8 \text{ m})}{1960 \text{ N}} \\ &= 1.10 \text{ m} \end{aligned}$$

26. The diagram shows a horizontal beam of negligible mass. The wall exerts a 42.0 N horizontal force on the lever. Find the weight of the load.



$$\sum F_x = F_x - T_{\parallel} = 0$$

$$T_{\parallel} = F_x = 42.0 \text{ N}$$

$$T_{\perp} = \frac{T_{\parallel}}{\tan 62^\circ} = 22.33 \text{ N}$$

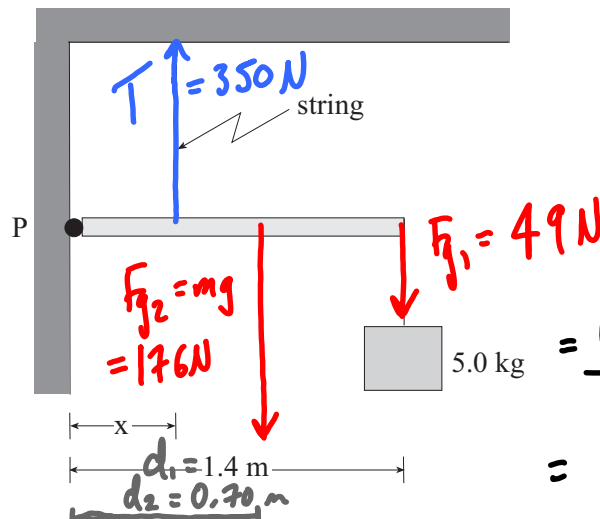
$$\tau_c = \tau_{cc}$$

$$F_g d_1 = T_{\perp} d_2$$

$$F_g = \frac{T_{\perp} d_2}{d_1} = \frac{(22.33 \text{ N})(1.30 \text{ m})}{1.80 \text{ m}} = 16.1 \text{ N}$$

- (A) 16.1 N
 B. 22.3 N
 C. 34.4 N
 D. 47.6 N

27. A uniform 18 kg beam hinged at P is held horizontal by a vertical string that can withstand a maximum tension of 350 N. A 5.0 kg mass is suspended from the end of the beam as shown.



$$\tau_c = \tau_{cc}$$

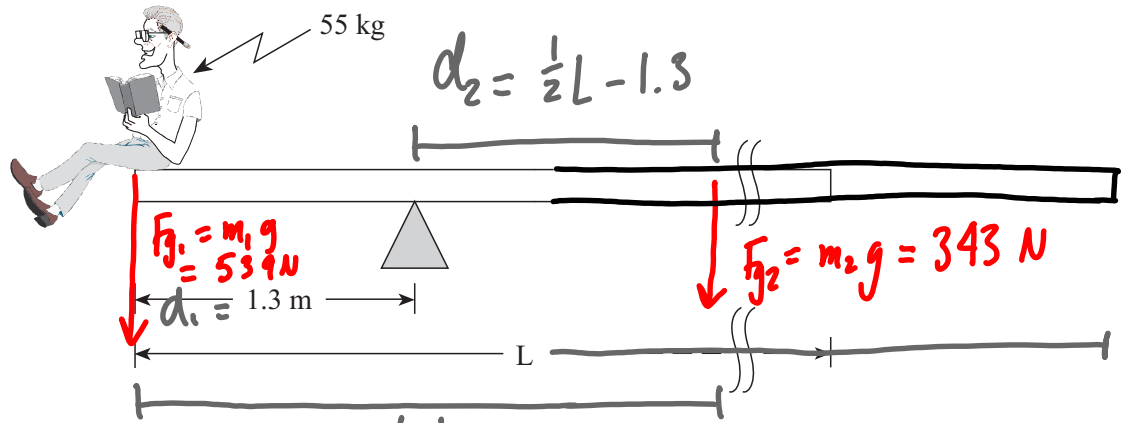
$$F_g d_1 + F_{g2} d_2 = T x$$

$$x = \frac{F_g d_1 + F_{g2} d_2}{T} = \frac{(49 \text{ N})(1.4 \text{ m}) + (176 \text{ N})(0.7 \text{ m})}{350 \text{ N}} = 0.55 \text{ m}$$

At what minimum distance, x, can the string be attached without breaking?

- A. 0.16 m
 B. 0.20 m
 (C) 0.55 m
 D. 0.70 m

28. A 35 kg uniform plank is balanced on one end by a 55 kg student as shown.



What is the overall length of this plank?

- A. 2.6 m
- B. 3.3 m
- C. 5.4 m
- D. 6.7 m

$$\tau_c = \tau_{cc}$$

$$F_{g2} d_2 = F_{g1} d_1$$

$$d_2 = \frac{F_{g1} d_1}{F_{g2}}$$

$$d_2 = \frac{(539\text{ N})(1.3\text{ m})}{343\text{ N}}$$

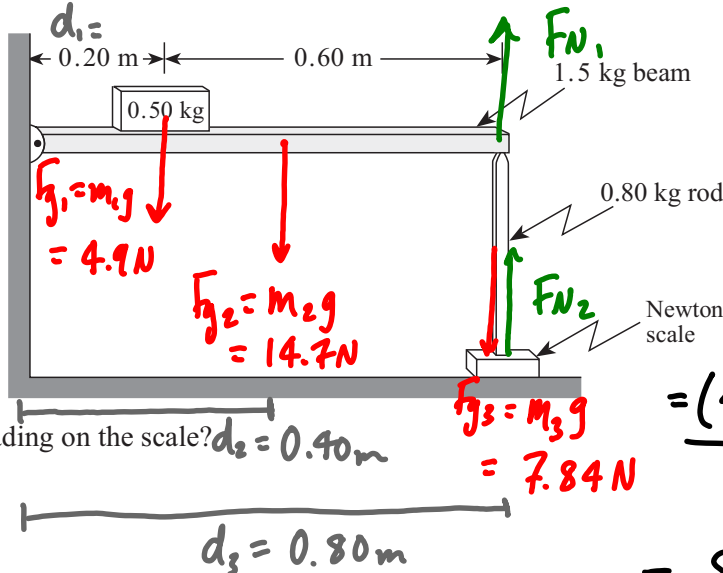
$$= 2.04\text{ m}$$

$$d_2 = \frac{1}{2}L - 1.3$$

$$L = 2(d_2 + 1.3)$$

$$= \underline{6.69\text{ m}}$$

29. A uniform 1.5 kg beam hinged at one end supports a 0.50 kg block. The beam is held level by a vertical 0.80 kg rod resting on a Newton scale at the other end.



What is the reading on the scale?

- A. 8.6 N
- B. 9.1 N
- C. 16 N
- D. 27 N

$$\tau_c = \tau_{cc}$$

$$F_{g1} d_1 + F_{g2} d_2 = F_{N1} d_3$$

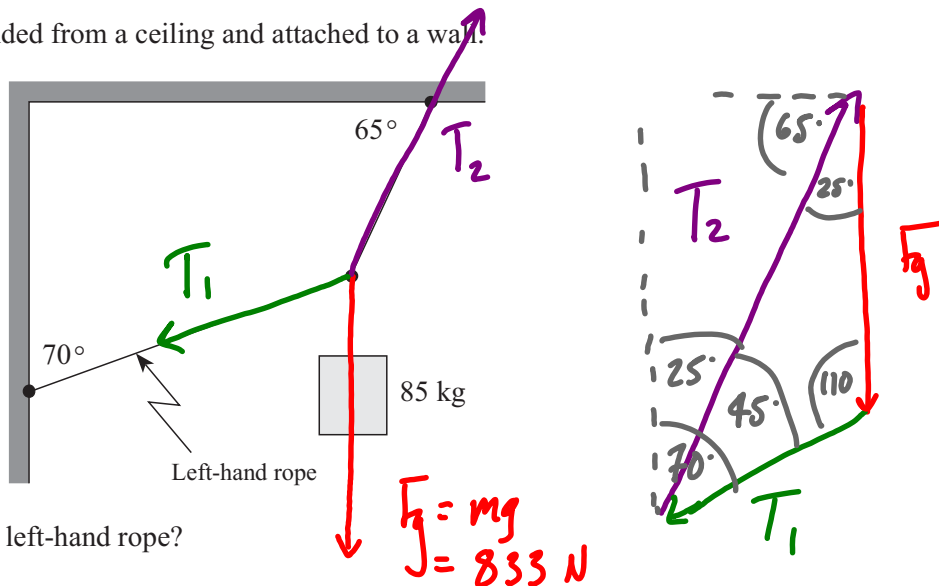
$$F_{N1} = \frac{F_{g1} d_1 + F_{g2} d_2}{d_3}$$

$$= \frac{(4.9\text{ N})(0.20\text{ m}) + (14.7\text{ N})(0.40\text{ m})}{(0.80\text{ m})}$$

$$= 8.575\text{ N}$$

$$F_{N2} = F_{N1} + F_{g3} = 16.4\text{ N}$$

30. An 85 kg object is suspended from a ceiling and attached to a wall.



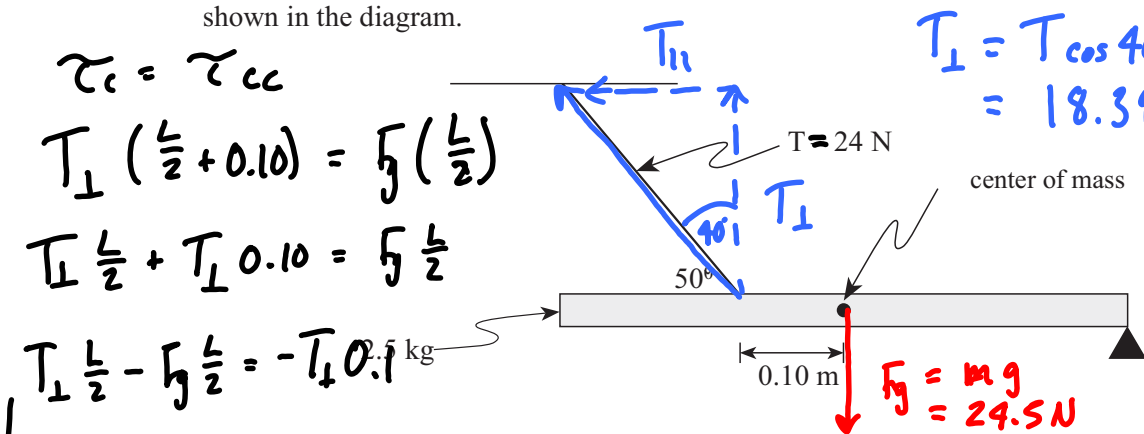
What is the tension in the left-hand rope?

- A. 280 N
- B. 350 N
- C. 500 N
- D. 1100 N

$$\frac{\sin 110^\circ}{T_2} = \frac{\sin 45^\circ}{833 \text{ N}}$$

$$T_2 = 833 \frac{\sin 110^\circ}{\sin 45^\circ} = 1107 \text{ N}$$

31. A uniform 2.5 kg beam, pivoted at its right end, is held in a horizontal position by a cable as shown in the diagram.



If the cable is attached 0.10 m to the left of the beam's centre of gravity, how long is the beam?

- A. 0.34 m
- B. 0.60 m
- C. 1.2 m
- D. 9.6 m

$$\tau_c = \tau_{cc}$$

$$T_{\perp} \left(\frac{L}{2} + 0.10 \right) = F_g \left(\frac{L}{2} \right)$$

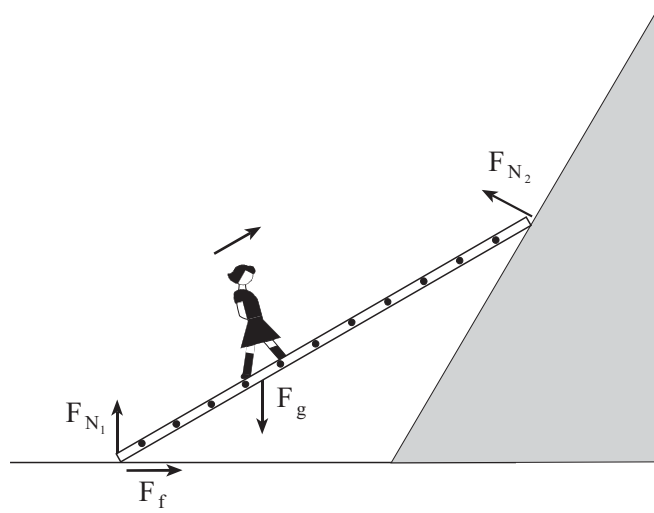
$$T_{\perp} \frac{L}{2} + T_{\perp} 0.10 = F_g \frac{L}{2}$$

$$T_{\perp} \frac{L}{2} - F_g \frac{L}{2} = -T_{\perp} 0.1$$

$$\frac{L}{2} (T_{\perp} - F_g) = -0.1 T_{\perp}$$

$$L = \frac{-0.2 T_{\perp}}{T_{\perp} - F_g} = \frac{-0.2 (18.39 \text{ N})}{(18.39 - 24.5)} = 0.60 \text{ m}$$

32. The diagram shows the forces acting on a massless ladder resting on the floor and a frictionless



As a person walks up the stationary ladder, what happens to the magnitude of the forces F_{N_1} and F_{N_2} ?

	MAGNITUDE OF F_{N_1}	MAGNITUDE OF F_{N_2}
A.	Decreases	Decreases
B.	Decreases	Increases
C.	Increases	Decreases
D.	Increases	Increases

33. A trailer carrying a boat is supported by a scale which initially reads 48 kg. The boat (and therefore its centre of gravity) is moved 0.15 m further back on the trailer. The scale now reads 37 kg. Find the mass of the boat.

Position 1

$$\tau_c = \tau_{cc}$$

$$F_{N_1} (6.0 \text{ m}) = F_g d_1 \quad \textcircled{1}$$

Position 2

$$\tau_c = \tau_{cc}$$

$$F_{N_2} (6.0) = F_g (d_1 - 0.15)$$

$$F_{N_2} (6.0) = F_g d_1 - 0.15 F_g \quad \textcircled{2}$$

- A. 440 kg
- B. 1600 kg**
- C. 1700 kg
- D. 3400 kg

subtract $\textcircled{1} - \textcircled{2}$

$$6.0 F_{N_1} = F_g d_1$$

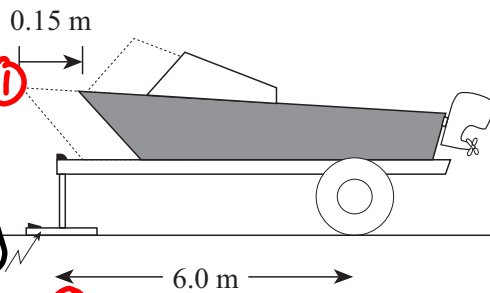
$$-(6.0 F_{N_2} = F_g d_1 - 0.15 F_g)$$

$$m = \frac{F_g}{g}$$

$$= 440 \text{ kg}$$

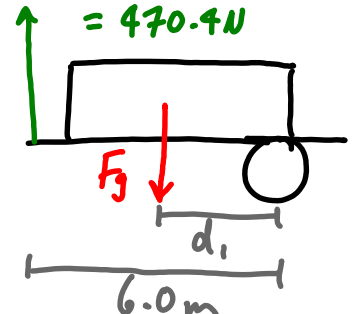
$$6.0 F_{N_1} - 6.0 F_{N_2} = 0.15 F_g$$

$$F_g = \frac{6.0 F_{N_1} - 6.0 F_{N_2}}{0.15} = 4312 \text{ N}$$

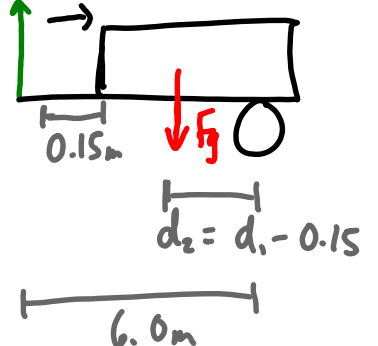


$$F_{N_1} = (48)(9.80)$$

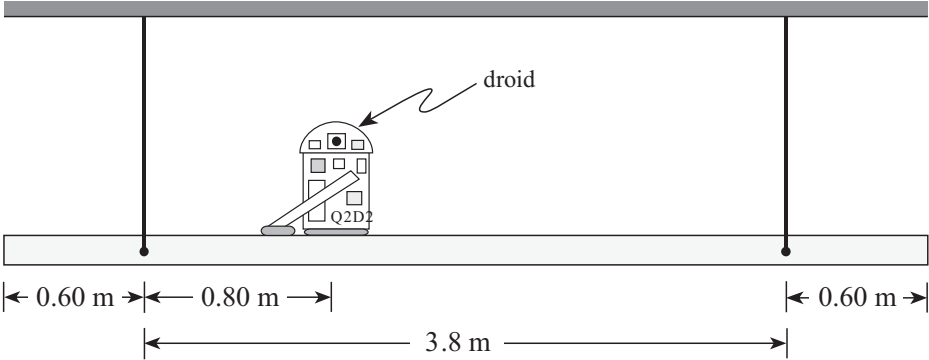
$$= 470.4 \text{ N}$$



$$F_{N_2} = (37)(9.80) = 362.6 \text{ N}$$



1. A 25 kg droid rests on a 5.0 m long shelf supported by two cables as shown. The mass of the shelf is 12 kg.

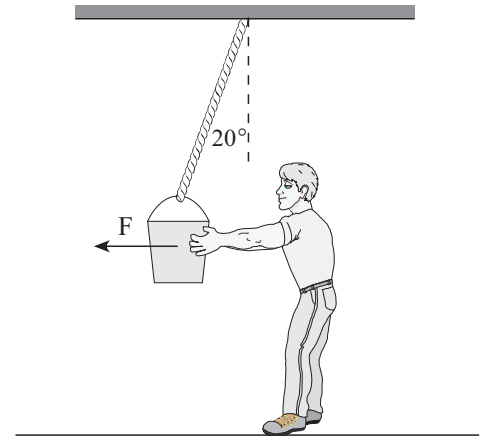


Find the tension in each cable.

(7 marks)

2. Peter exerts a horizontal force F on a 12 kg bucket of concrete so that the supporting rope makes an angle of 20° with the vertical.

- a) Find the tension force in the supporting rope. **(3 marks)**



- b) Peter now exerts a new force which causes the rope to make a greater angle with the vertical. How will the tension force in the supporting rope change?

- The tension force will increase.
 The tension force will decrease.
 The tension force will remain the same.

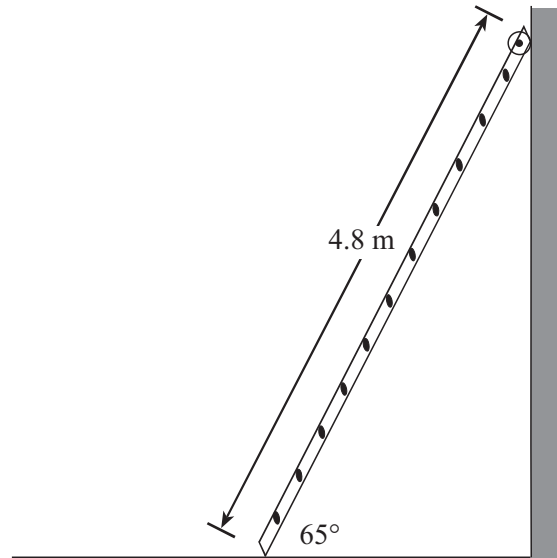
(Check one response.)

(1 mark)

- c) Using principles of physics, explain your answer to b).

(3 marks)

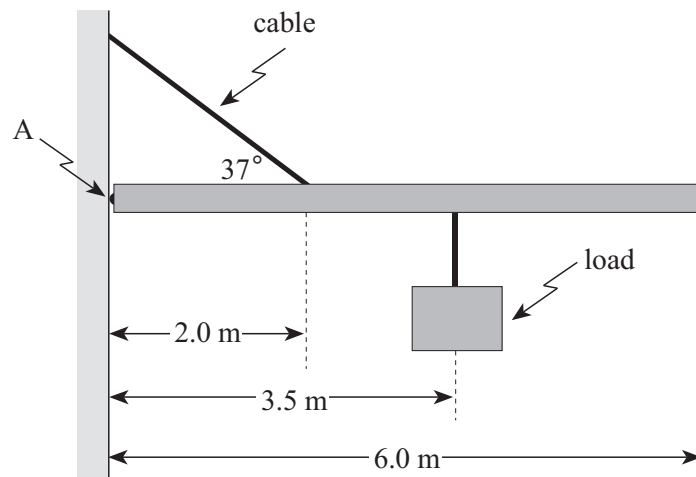
3. A uniform 4.8 m long ladder of mass 16 kg leans against a frictionless vertical wall as shown in the diagram below.



- a) Draw and label a free body diagram showing the forces acting on the ladder. **(2 marks)**

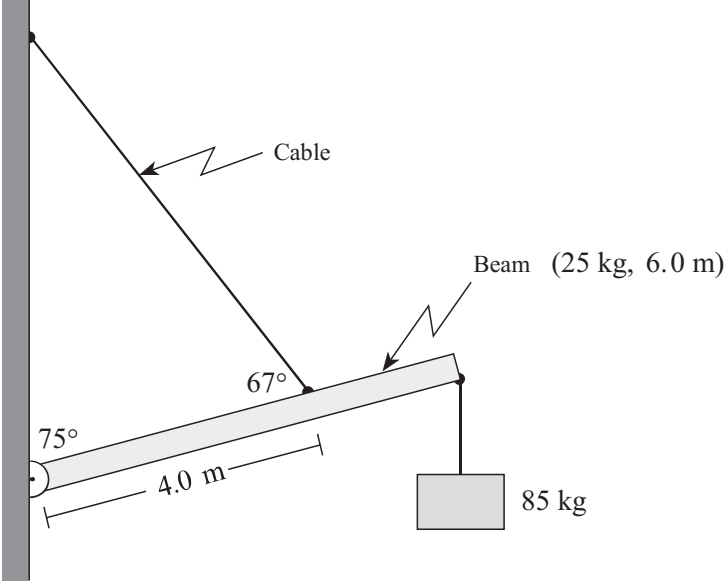
- b) What minimum force of friction is needed at the base of the ladder to keep it from sliding? **(5 marks)**

4. A uniform beam 6.0 m long, and with a mass of 75 kg, is hinged at A. The supporting cable keeps the beam horizontal.



If the maximum tension the cable can withstand is 2.4×10^3 N, what is the maximum mass of the load? **(7 marks)**

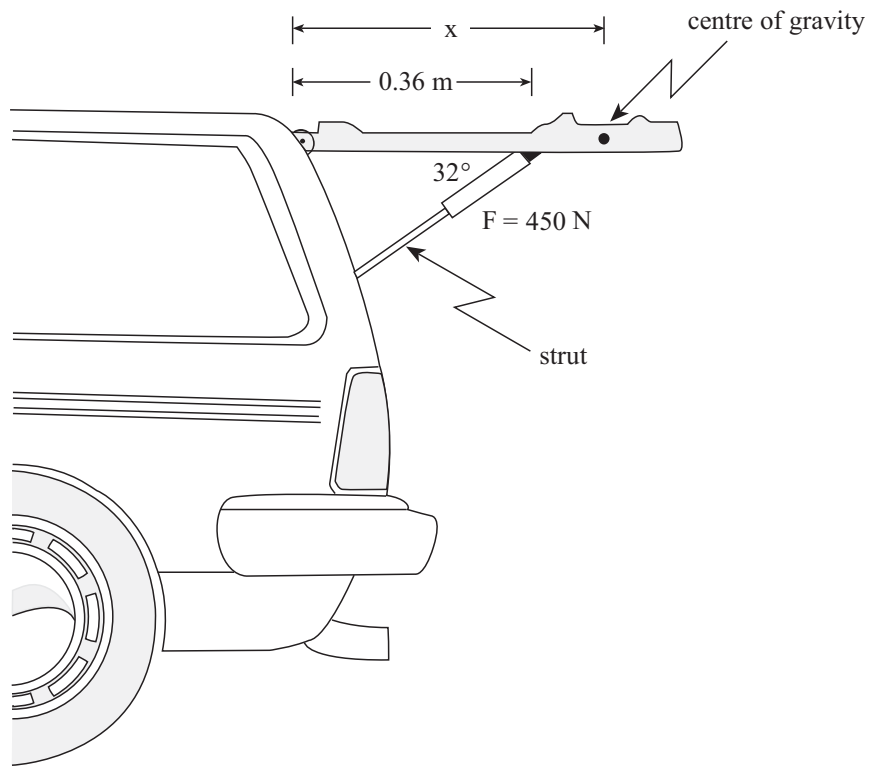
5. A 6.0 m uniform beam of mass 25 kg is suspended by a cable as shown. An 85 kg object hangs from one end.



What is the tension in the cable?

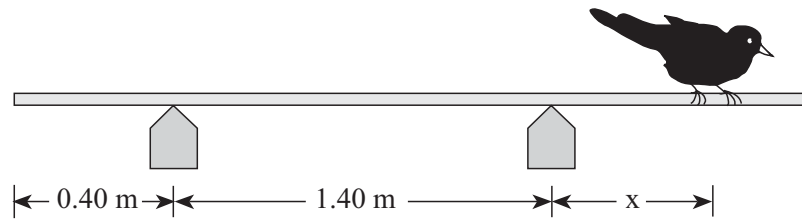
(7 marks)

6. The diagram shows the rear door of a station wagon supported horizontally by a strut. The mass of the door is 18 kg and the compression force in the strut is 450 N.



- b) At what distance, x , from the hinge is the centre of gravity of the door located? **(7 marks)**

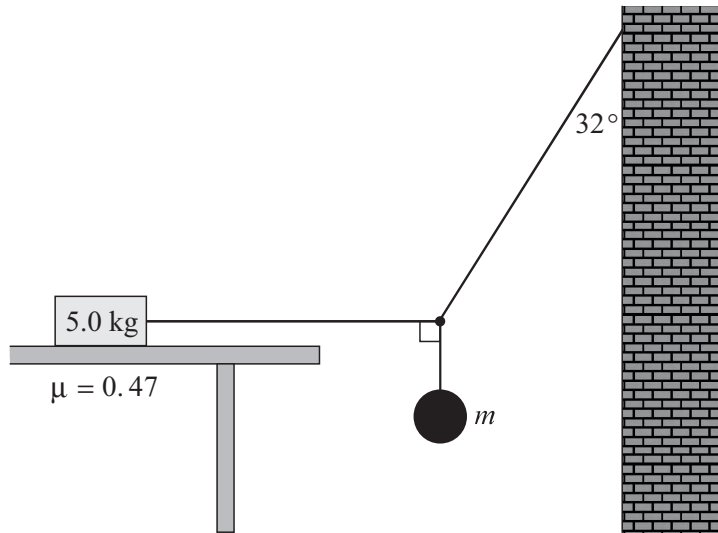
7. A 0.75 kg board of length 2.60 m initially rests on two supports as shown.



- a) What maximum distance, x , from the right-hand support can a 1.20 kg bird walk before the board begins to leave the left-hand support? **(5 marks)**

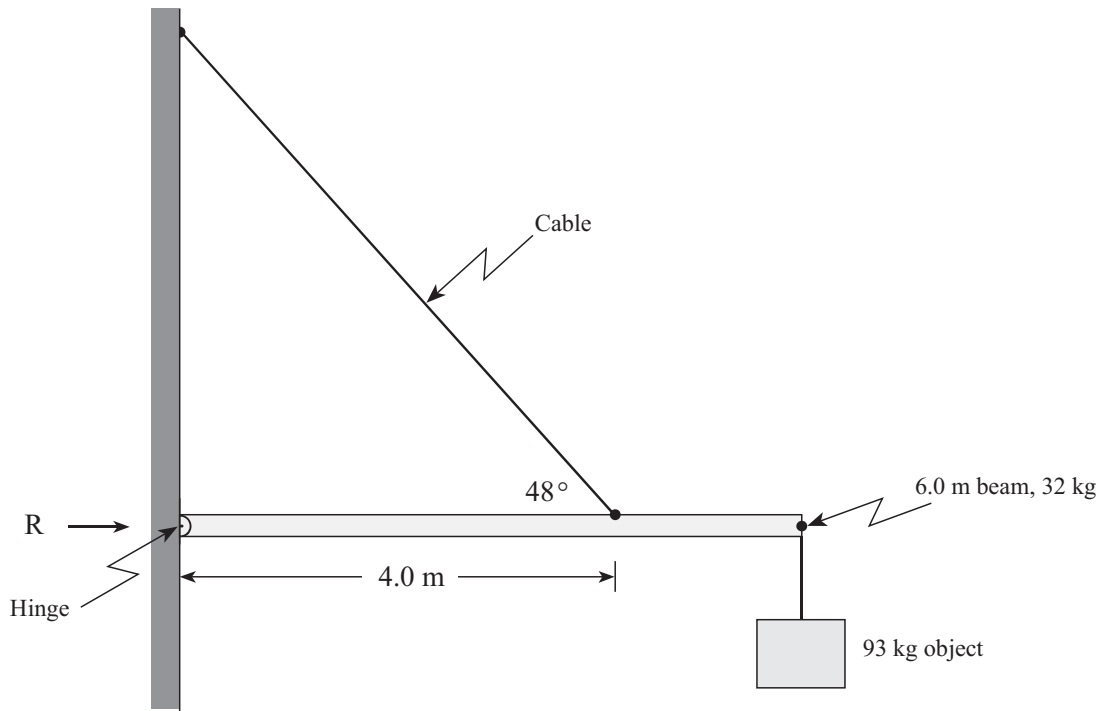
- b) What force does the right-hand support exert on the board at that instant? **(2 marks)**

8. An object of mass, m , is suspended by two cords connected to a wall and to a 5.0 kg block resting on a table as shown.



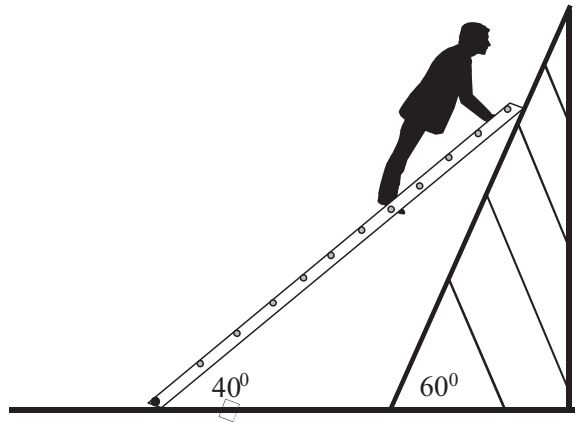
A coefficient of friction of 0.47 exists between the 5.0 kg block and the table. What is the maximum mass, m , that can be hung from the cords before the 5.0 kg block begins to move?
(7 marks)

9. A 6.0 m uniform beam of mass 32 kg is suspended horizontally by a hinged end and a cable. A 93 kg object is connected to one end of the beam.

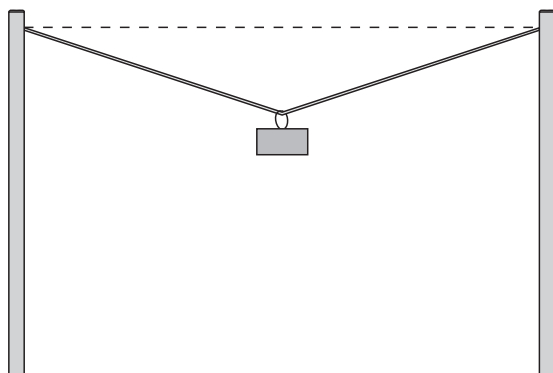


What is the magnitude and direction of the reaction force R that the hinge exerts on the beam? **(10 marks)**

10. A 65 kg person is $\frac{3}{4}$ of the way up a 25 kg uniform ladder as shown in the diagram below. The ladder is leaning against a frictionless surface inclined at 60° to the horizontal. What is the minimum coefficient of friction between the ladder and the floor necessary to maintain equilibrium? **(10 marks)**



11. A wire is stretched between two posts. A mass is suspended near the centre as shown below.



If the tension in the wire were increased, is it possible to make the wire perfectly horizontal?
Explain your answer in terms of forces. **(4 marks)**
