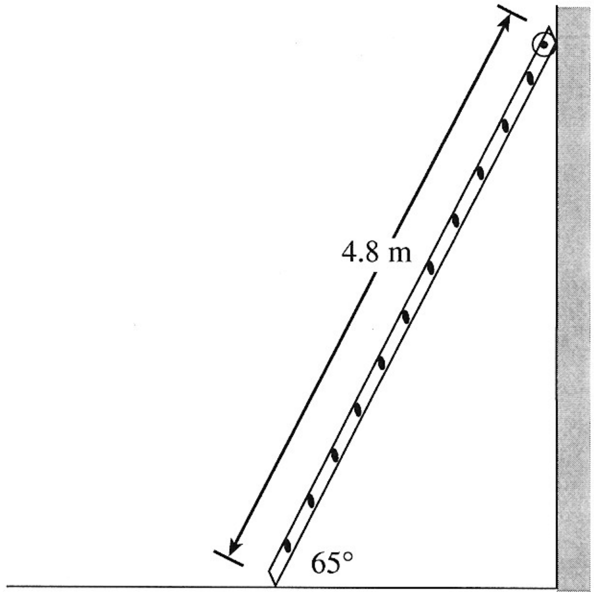
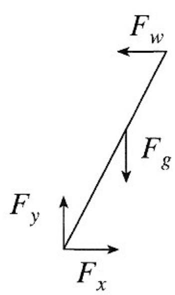
3. A uniform 4.8 m long ladder of mass 16 kg leans against a **frictionless** vertical wall as shown in the diagram below.




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




**2 marks**

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

$$\tau_{cw} = \tau_{ccw}$$

$$F_{g_\perp}(2.4) = F_{w_\perp}(4.8)$$ ← **3 marks**

$$(16)(9.8)(\cos 65)(2.4) = F_w \sin 65(4.8)$$

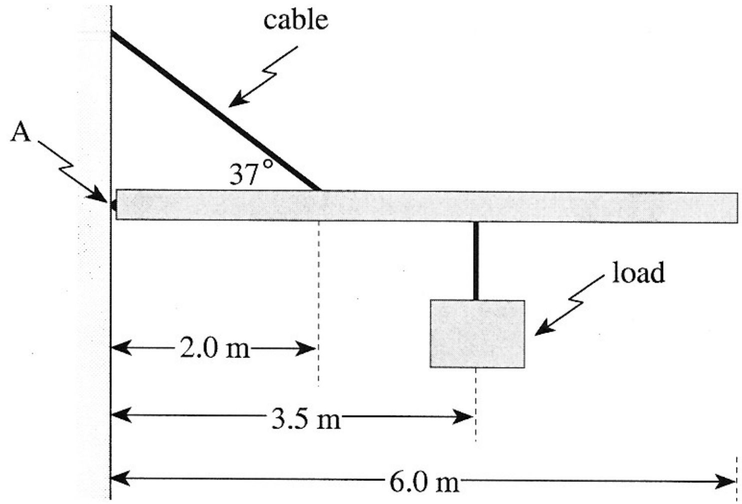
$$159 = F_w(4.35)$$

$$F_w = 37\text{ N}$$ ← **1 mark**

$$\sum F_x = 0 \quad F_x = F_w$$

$$F_f = 37\text{ N}$$ ← **1 mark**

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 $2.4 \times 10^3$ N, what is the maximum mass of the load?

**(7 marks)**

$\tau_{CW} = \tau_{CCW}$ ← **1 mark**

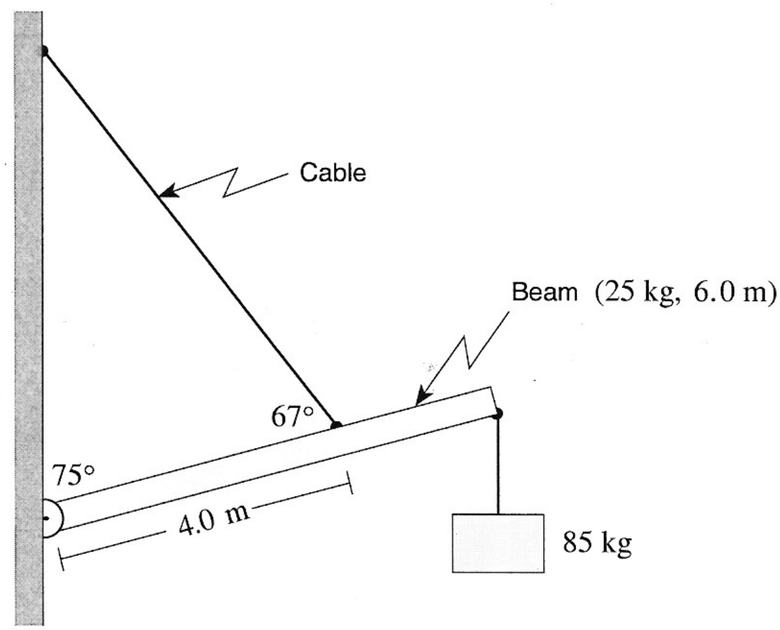
$$\left.\begin{aligned} F\perp &= (2.4\times10^3)\sin 37° \\ &= 1\ 444.3 \text{ N} \end{aligned}\right\} \leftarrow 2 \textbf{ marks}$$

∴ Using torque about A:

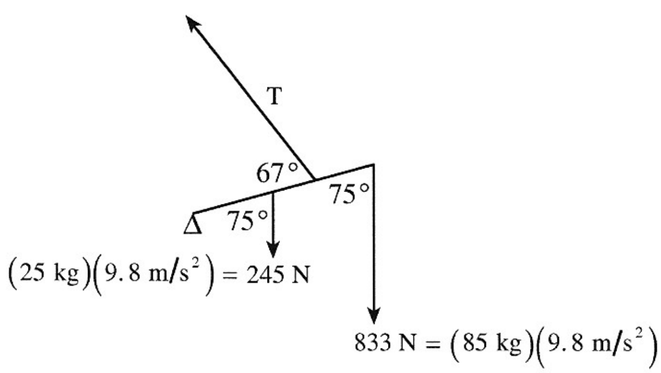
$3.0(735) + 3.5(F_L) = 1\ 444.3(2.0)$ ← 3 **marks**

$$\left.\begin{aligned} 2\ 205 + 3.5(F_L) &= 2\ 888.6 \text{ N} \\ 3.5(F_L) &= 683 \text{ N} \\ \text{Load} &= 195.4 \text{ N} \\ \text{Mass} &= \frac{F_L}{9.8} \\ &= 19.9 \text{ kg} \\ &= 20 \text{ kg} \end{aligned}\right\} \textbf{1 mark}$$

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)**




$$\Sigma\tau = 0$$

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

$$\tau_{245} + \tau_{833} = \tau_T \qquad \leftarrow \textbf{1 mark}$$

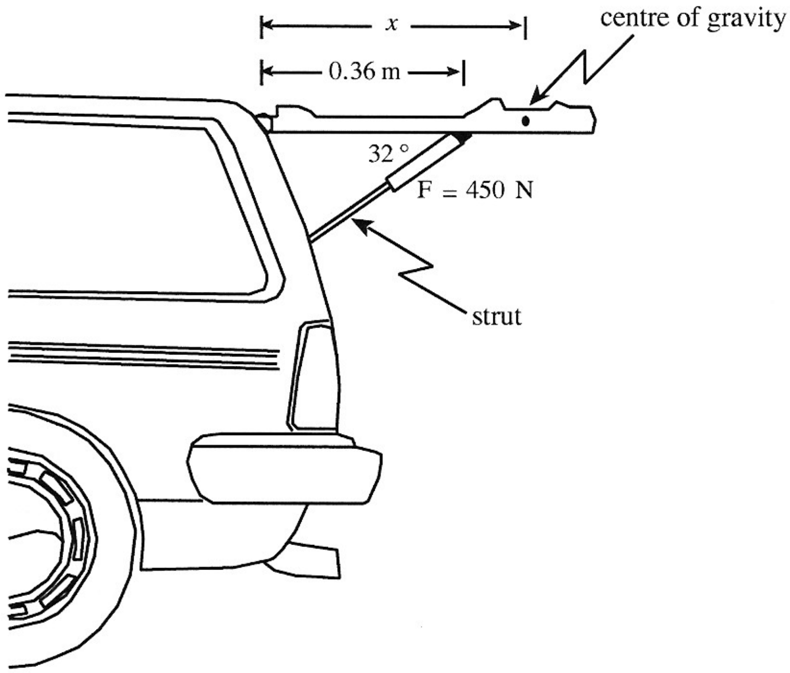
$$3.0\ \text{m}(245\ \text{N})\sin 75° + 6.0\ \text{m}(833\ \text{N})\sin 75° = 4.0\ \text{m}\ T\sin 67° \qquad \leftarrow \textbf{5 marks}$$

$$710\ \text{N}\cdot\text{m} + 4\,830\ \text{N}\cdot\text{m} = 3.68\ \text{m}\ T$$

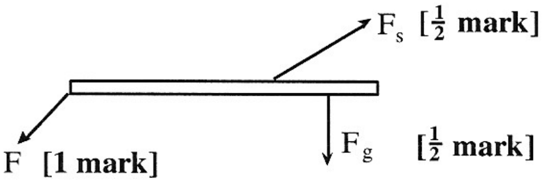
$$5\,540\ \text{N}\cdot\text{m} = 3.68\ \text{m}\ T$$

$$1\,500\ \text{N} = T \qquad \leftarrow \textbf{1 mark}$$

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.




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




b) At what distance, $x$, from the hinge is the centre of gravity of the door located? **(5 marks)**

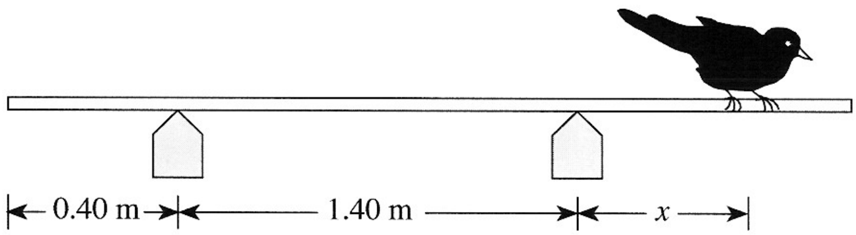
$$\tau_c = \tau_{cc}$$

$$mgx = F_s(d)\sin\theta \qquad \leftarrow \textbf{2 marks}$$

$$18(9.8)x = 450(0.36)\sin 32° \qquad \leftarrow \textbf{2 marks}$$

$$x = 0.49 \text{ m} \qquad \leftarrow \textbf{1 mark}$$

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)**

Take torques about right support

$$\tau_C = \tau_{CC} \qquad \leftarrow \textbf{1 mark}$$

$$1.20(9.8)x = 0.75(9.8)\underbrace{(0.50)}_{\textbf{1 mark}} \qquad \leftarrow \textbf{2 marks}$$

$$x = 0.31\text{ m} \qquad \leftarrow \textbf{1 mark}$$

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

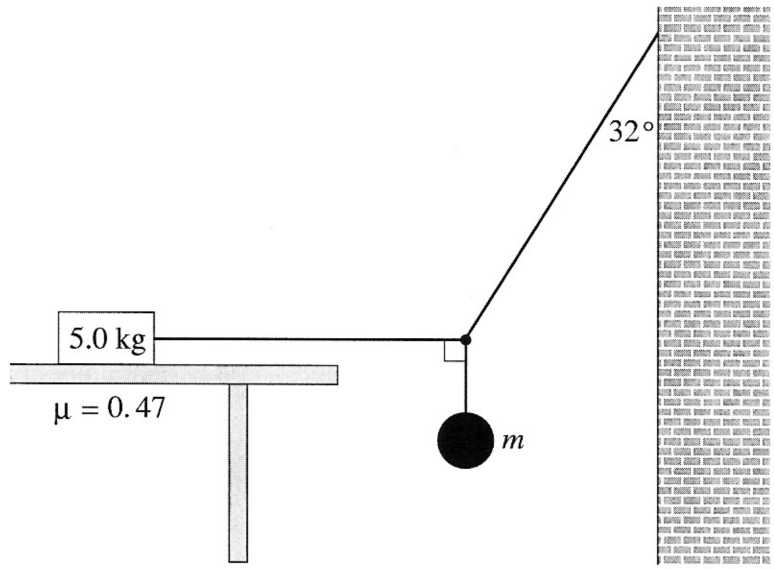
$$F_{up} = F_{down} \qquad \tfrac{1}{2}\ \textbf{mark}$$

$$F = 1.2(9.8) + 0.75(9.8) \qquad \tfrac{1}{2}\ \textbf{mark}$$

$$F = 11.76 + 7.35 \qquad \tfrac{1}{2}\ \textbf{mark}$$

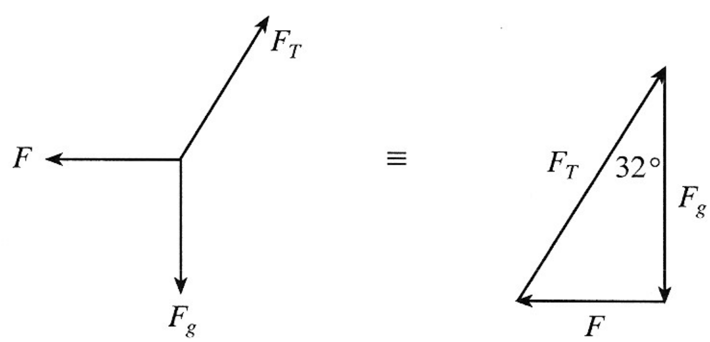
$$= 19\text{ N} \qquad \tfrac{1}{2}\ \textbf{mark}$$

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)**




$$F_f = \mu F_N$$

$$= 0.47 \times 5.0 \times 9.8$$

$$= 23 \text{ N}$$ ← **2 marks**

$$F_g = \frac{F}{\tan 32^\circ}$$

$$mg = \frac{F}{\tan 32^\circ}$$

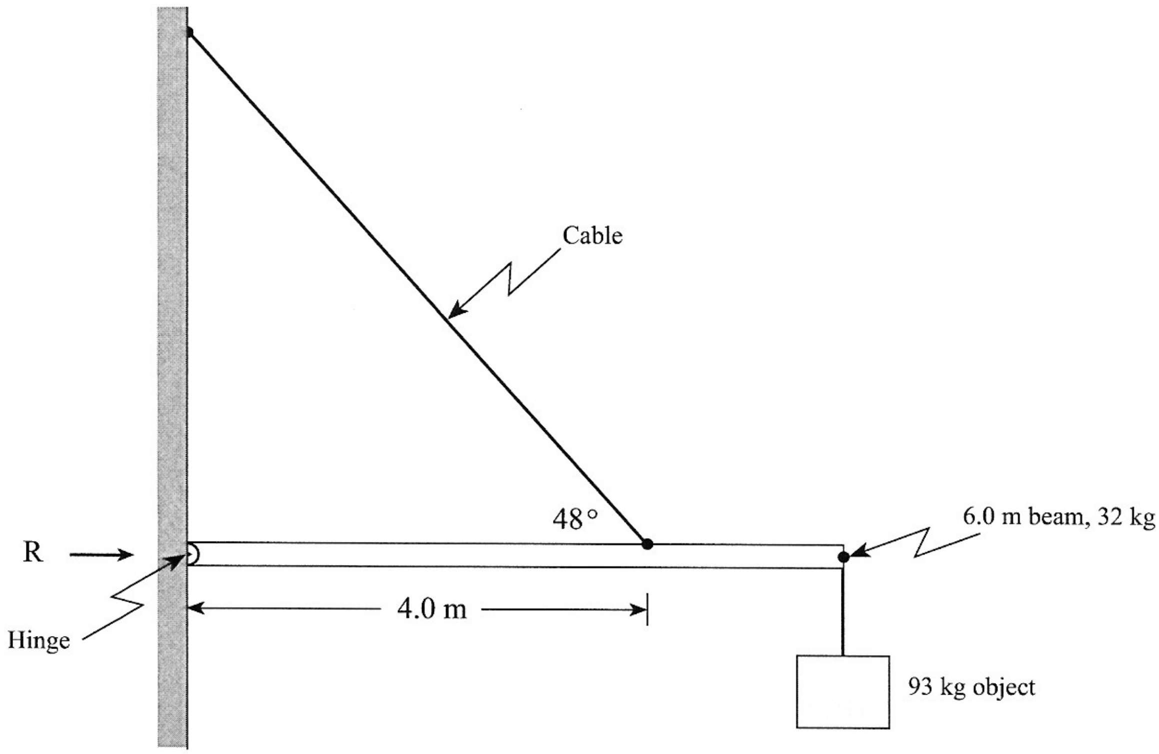
$$m = \frac{F}{g \times \tan 32^\circ}$$

$$m = \frac{23}{9.80 \times \tan 32^\circ}$$

} ← **4 marks**

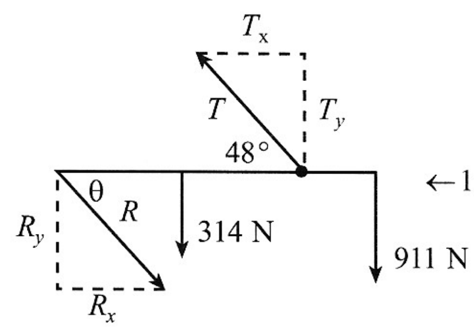
$$m = 3.8 \text{ kg}$$ ← **1 mark**

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)**

$$\tau_c = \tau_{cc} \text{ about the hinge}$$
$$3.0(314) + 6.0(911) = 4.0(T)\sin 48°$$
$$942 + 5\,470 = 2.97\,T$$
$$2\,160 \text{ N} = T$$
← **2 marks**




← **1 mark**

$$T_x = R_x$$
$$T\cos 48 = R_x$$
$$2\,160\cos 48 = R_x$$
$$R_x = 1\,400 \text{ N } (1.4 \times 10^3 \text{ N})$$
← **1 mark**

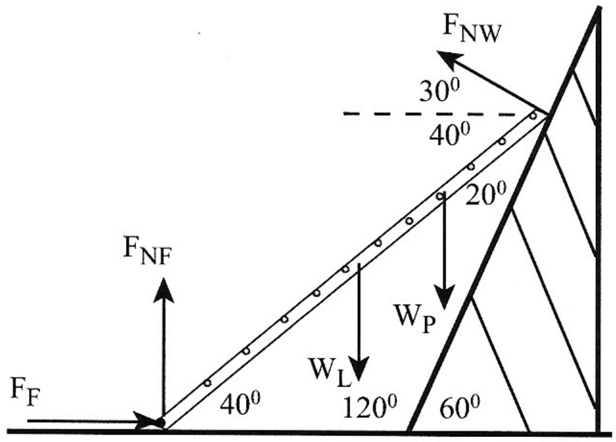
$$\Sigma\tau = 0 \text{ about the hinge}$$
$$(314)(3.0) - T_y(4.0) + 911(6.0) = 0$$
$$T_y = 1\,600 \text{ N}$$
← **2 marks**

$$R_y = T_y - W_{Load} - W_{Beam}$$
$$= 1600\text{N} - 911\text{N} - 314\text{N}$$
$$= 375\text{N}$$
← **2 marks**

$$R = \sqrt{R_x^2 + R_y^2}$$
$$= 1450\text{N} = 1.45 \times 10^3 \text{N}$$
← **1 mark**

$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right)$$
$$\theta = 15^0 \text{ below horiz.}$$
← **1 mark**

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 $60^0$ to the horizontal. What is the minimum coefficient of friction between the ladder and the floor necessary to maintain equilibrium? **(10 marks)**




$$\left.\begin{aligned} W_L &= (25)(9.8) = 245\text{N} \\ W_P &= (65)(9.8) = 637\text{N} \end{aligned}\right\} 1\text{ mark}$$

Identify all angles } 1 mark

$$\sum \tau_{ccw} = \sum \tau_{cw}$$

$$\left.\begin{aligned} F_{NW}(\sin 70)d &= W_L(\sin 50)\frac{1}{2}d + W_P(\sin 50)\frac{3}{4}d \\ F_{NW}(\sin 70)d &= (245)(\sin 50)\frac{1}{2}d + (637)(\sin 50)\frac{3}{4}d \\ F_{NW} &= 489\text{N} \end{aligned}\right\} 3\text{ marks}$$

$$\sum F_x = 0$$

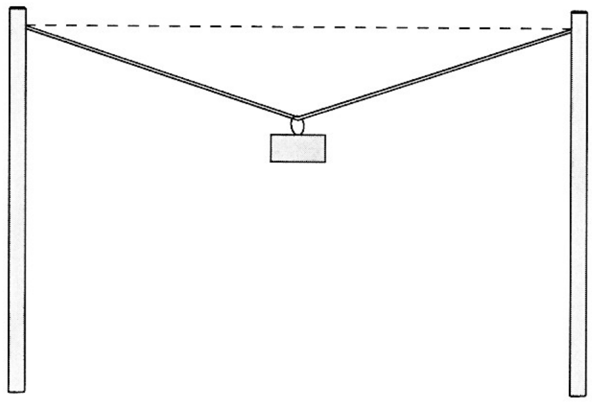
$$\left.\begin{aligned} F_F &= F_{NW}(\cos 30) \\ &= (489)(\cos 30) \\ &= 423\text{N} \end{aligned}\right\} 1\text{ mark}$$

$$\sum F_y = 0$$

$$\left.\begin{aligned} F_{NF} &= W_l + W_P - F_{NW}(\sin 30) \\ &= 245\text{N} + 637\text{N} - (489)(\sin 30) \\ &= 638\text{N} \end{aligned}\right\} 2\text{ marks}$$

$$\left.\begin{aligned} F_F &= \mu F_{NF} \\ \therefore \mu &= \frac{F_F}{F_{NF}} = \frac{423}{637} = 0.66 \end{aligned}\right\} 2\text{ marks}$$

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)**

No, it is not possible to make the wire perfectly horizontal. Since the mass has a vertical force of gravity acting on it, the tension in the wire must have an opposite vertical component. A horizontal tension has no vertical component; therefore, it is not possible to make the wire perfectly horizontal.