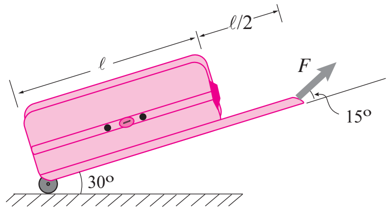
7.2.1 A suitcase with bad wheels has length $\ell = 0.5\,\mathrm{m}$ and thickness (height) of $\ell = 0.25\,\mathrm{m}$ is pulled along steadily with a force $F = 100\,\mathrm{N}$ as shown in the figure.

a) Find the weight W of the suitcase.

b) Find the ground force on the wheel (both magnitude and direction).

c) What is force amplification if you consider F as the input and W as the output.



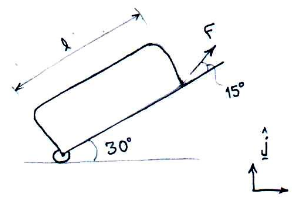
Problem 7.1

6.2.1

Find a) weight of suitcase

b) ground force.

c) force amplification.

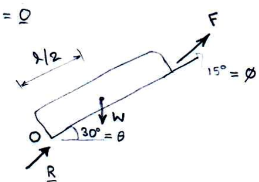


a) weight of suitcase:

Moment balance about 'O', $\Sigma \underline{M}_{/o} = \underline{0}$

$$\frac{\ell}{2}(\cos\theta\,\hat{\imath} + \sin\theta\,\hat{\jmath}) \times W(-\hat{\jmath}) + \ell[\cos(\theta)\,\hat{\imath} + \sin(\theta)\,\hat{\jmath}] \times F[\cos(\theta+\phi)\,\hat{\imath} + \sin(\theta+\phi)\,\hat{\jmath}] = \underline{0}$$

$$\Rightarrow \left\{-\frac{W\ell}{2}\cos\theta\,\hat{k} + F\ell\cos\theta\sin(\theta+\phi)\,\hat{k} - F\ell\sin\theta\cos(\theta+\phi)\,\hat{k} = \underline{0}\right\}$$



$$\{\ \}\cdot\hat{k} \Rightarrow -\frac{W\ell}{2}\cos\theta + F\ell\sin[(\theta+\phi)-\theta] = 0$$

Given that F=10

$$\Rightarrow W = 2F\frac{\sin\phi}{\cos\theta} = 2\times 100\,\mathrm{N}\,\frac{\sin 15^\circ}{\cos 30^\circ} \Rightarrow \boxed{W = 59.77\ \mathrm{N}}$$

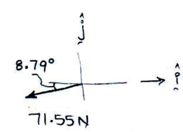
b) Applying force balance, $\Sigma \underline{F} = \underline{0}$

$$\Rightarrow \underline{R} + W(-\hat{\jmath}) + F\cos(\theta+\phi)\,\hat{\imath} + F\sin(\theta+\phi)\,\hat{\jmath} = \underline{0}$$

$$\Rightarrow \underline{R} = -F\cos(\theta+\phi)\,\hat{\imath} + [W - F\sin(\theta+\phi)]\,\hat{\jmath}$$

$$\Rightarrow \underline{R} = -100\,\mathrm{N}\cos 45^\circ\,\hat{\imath} + [59.77\,\mathrm{N} - 100\,\mathrm{N}\sin 45^\circ]\,\hat{\jmath}$$

$$\therefore \underline{R} = -70.71\,\mathrm{N}\,\hat{\imath} - 10.94\,\mathrm{N}\,\hat{\jmath}$$



Magnitude, $|\underline{R}| = \sqrt{(-70.71)^2 + (-10.94)^2}\ \mathrm{N}$

$$\Rightarrow \boxed{|\underline{R}| = 71.55\mathrm{N}}$$

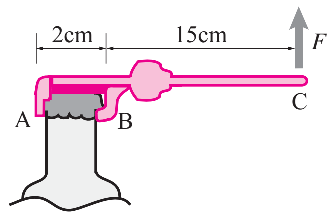
Direction, $\tan\psi = \frac{-10.94}{-70.71} \Rightarrow \boxed{\psi = 8.79^\circ}$ as shown in the figure.

c) Considering F as input and W as output,

Force amplification, $= \boxed{\frac{W}{F} = 0.598}$

Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

7.2.3 A bottle-opener ABC contains a cut-out AB of approximate diameter 2 cm that clamps on the bottle cap. The arm BC is approximately 15 cm long. If the cap is opened by applying a vertical force $F = 10\,\text{N}$ at C, find the force on the cap at B.



Problem 7.3

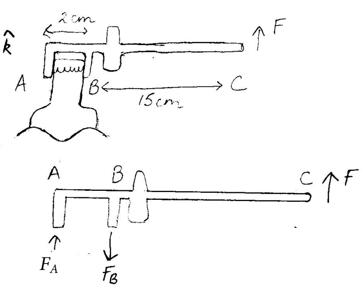
6·2·3 $\sum \vec{M}_A = \vec{0}$; $(\sum \vec{M}_A = \vec{0}) \cdot \hat{k}$

$\Rightarrow F(AC) - F_B(AB) = 0$

$\Rightarrow 10\text{N}(17\text{cm}) - F_B(2\text{cm}) = 0$

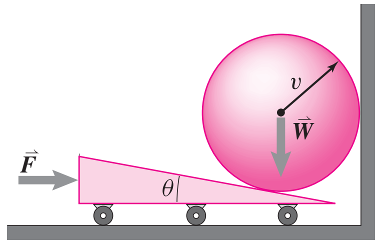
$\Rightarrow 170\text{Ncm} = 2F_B\text{cm}$

$\Rightarrow \boxed{F_B = 85\text{N}}$



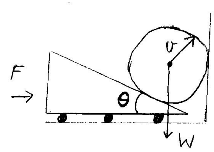
Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

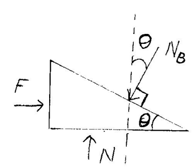
7.2.5 Assuming all frictionless contacts, find the force F on the wedge required to lift the sphere weighing 500 N if the wedge angle $\theta = 10°$.



Problem 7.5

6·2·6 For the wedge, $\Sigma\vec{F} = \vec{0}$



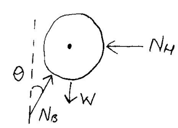


$(\Sigma\vec{F} = \vec{0}).\hat{\imath} \Rightarrow F - N_B \sin\theta = 0$

$\Rightarrow F = N_B \sin\theta$ ①

$(\Sigma\vec{F} = \vec{0}).\hat{\jmath} \Rightarrow N - N_B \cos\theta = 0$

$\Rightarrow N = N_B \cos\theta$ ②.



For the sphere, $\Sigma\vec{F} = \vec{0}$

$(\Sigma\vec{F} = \vec{0}).\hat{\imath} \Rightarrow N_B \sin\theta - N_H = 0 \Rightarrow N_H = N_B \sin\theta$ ③

$(\Sigma\vec{F} = \vec{0}).\hat{\jmath} \Rightarrow N_B \cos\theta - W = 0 \Rightarrow W = N_B \cos\theta$ ④

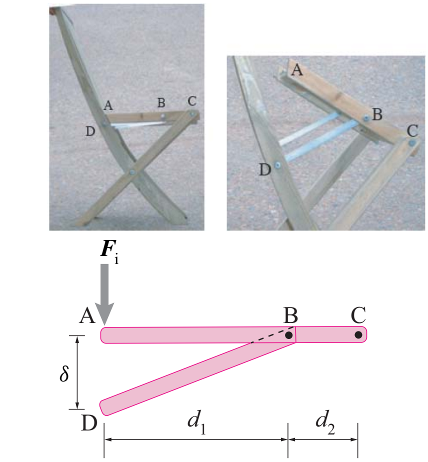
W and θ are known. Using ① and ④, $\frac{F}{W} = \tan\theta \Rightarrow F = W\tan\theta$

$\Rightarrow F = 500\,N \tan 10°$

$\boxed{\Rightarrow F = 88.163\,N}$

Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

7.2.7 A toggle-like mechanism is used in a folding chair shown in the pictures here. The metallic link DB gets almost parallel to the seating plank AC when the chair is open. Given the dimensions $d_1 = 30\,\text{cm}, d_2 = 10\,\text{cm}, \delta = 2\,\text{cm}$ and the force at A, $F_i = 500\,\text{N}$, find the force in the link DB. Why is this force so big or small? In practice why would you never see such a large force?



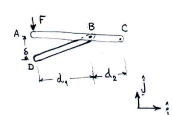
Problem 7.7

Answer:
The force is so big because of the toggle mechanism: because DB is nearly parallel to AC, to balance moments about C the force in DB has to be huge. Look at the leg whose top is at D. That leg could only have a big force on it at D if the bottom of the leg was restrained. So the big force would only occur if there was, say, a cable connecting the bottoms of the two legs.

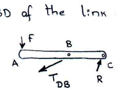
6.2.8

Find the force in the link DB.

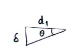
Given that, $\delta = 2\text{cm}$, $d_1 = 30\text{cm}$, $d_2 = 10\text{cm}$, and $F = 500\text{N}$.



Consider the FBD of the link AC



Applying moment balance about C, $\Sigma \underline{M}_{/c} = \underline{0}$



$$\Rightarrow (d_1+d_2)(-\hat{\underline{i}}) \times F(-\hat{\underline{j}}) + d_2(-\hat{\underline{i}}) \times (-T_{DB}\cos\theta\,\hat{\underline{i}} - T_{DB}\sin\theta\,\hat{\underline{j}}) = \underline{0}$$

$$\Rightarrow \left\{ F(d_1+d_2)\,\hat{\underline{k}} + T_{DB}\sin\theta\, d_2\,\hat{\underline{k}} = \underline{0} \right\}$$

$$\{\ \}\cdot\hat{\underline{k}} \Rightarrow \quad T_{DB} = -\frac{F(d_1+d_2)}{d_2\sin\theta} \qquad \sin\theta = \frac{\delta}{\sqrt{\delta^2+d_1^2}}$$

$$\Rightarrow T_{DB} = -\frac{500\text{ N}\,(40\text{ cm})}{10\text{ cm}\left[\frac{2\text{cm}}{\sqrt{(2\text{cm})^2+(30\text{cm})^2}}\right]} \Rightarrow \boxed{T_{DB} = -30{,}066.6\text{ N}}$$

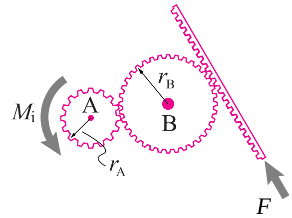
From the given dimensions, $\boxed{\theta = 3.8^\circ}$

As the angle between AC and DB is very small, the force in DB has to be huge in order to balance the moments about the point C.

The bottom of the leg connected to D is not constrained. So, the big force would only occur if the bottoms of the two legs are connected.

Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

7.2.9 The input gear A of radius r_A = 10 cm drives gear B that is one and a half times bigger than gear A. Gear B, in turn, drives a rack. If the input torque on gear A is M_i = 30 N·m, find the load F on the rack.



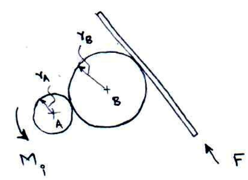
Problem 7.9

6.2.10

Find the force F given $r_B = 1.5\, r_A$

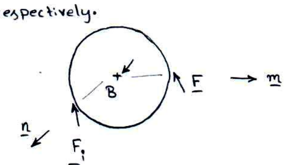
M_i = 30 Nm

r_A = 10 cm.



Consider the FBD of gear B

Let $\underline{m}$ and $\underline{n}$ be the unit vectors from B to contact point of rack on gear B and B to A respectively.



Taking moment balance about point B.

$$\Sigma \underline{M}_{/B} = \underline{0}$$

$$\Rightarrow \quad r_B \underline{m} \times \underline{F} + r_B \underline{n} \times \underline{F}_i = \underline{0}$$

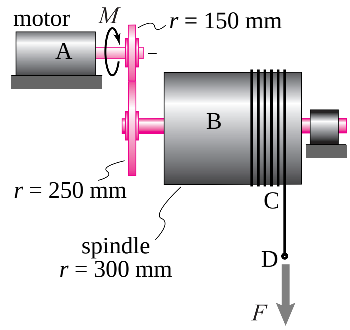
$$\Rightarrow \quad \{ F r_B \hat{\underline{k}} - r_B F_i \hat{\underline{k}} = \underline{0} \}$$

$$\{ \} \cdot \hat{\underline{k}} \quad \Rightarrow \quad F = F_i = \frac{M_i}{r_A}$$

$$\therefore \quad F = 30\ \text{Nm} \cdot \left(\frac{1}{10\,\text{cm}}\right) \Rightarrow \boxed{F = 300\ \text{N}}$$

Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

7.2.13 The gear train and spindle shown in the figure are used for hoisting heavy loads. For the dimensions given, if the load $F = 2\,\text{kN}$, find the torque M that the motor A must apply for equilibrium.

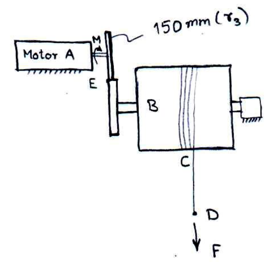


Problem 7.13

6.2.14

Find the torque M that the motor A must apply for equilibrium.

Consider the FBD of B.

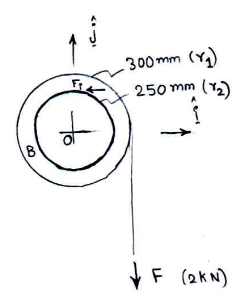


Let the input force acting at the point E be F_i in $-\hat{\imath}$ direction.

Applying Moment balance about 'O'

$$\sum \underline{M}_{/o} = \underline{0}$$

$$\Rightarrow \quad r_1 \hat{\imath} \times F(-\hat{\jmath}) + r_2 \hat{\jmath} \times F_i(-\hat{\imath}) = \underline{0}$$



$$\Rightarrow \quad \{ -F r_1 \hat{k} + F_i r_2 \hat{k} = \underline{0} \}$$

$\{\}\cdot\hat{k}$

$$\Rightarrow \quad F_i = \frac{r_1}{r_2} F$$

$\therefore$ The torque needed at motor A, $M = F_i r_3$

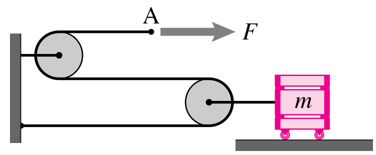
$$\Rightarrow \quad M = \frac{r_1 r_3}{r_2} F$$

$$\Rightarrow \quad M = \frac{\overset{12}{\cancel{300\text{ mm}}} \cdot 15\cancel{0}\text{ mm}}{\cancel{25\cancel{0}\text{ mm}}} \times 2\text{ kN} = 12 \cdot 30 \text{ mm kN}$$

$$\therefore \quad \boxed{M = 360 \text{ Nm}}$$

Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

7.2.18 A force $F = 100\,\mathrm{N}$ acts at A. The pulleys are frictionless. Find the force on the box applied by the pulley.

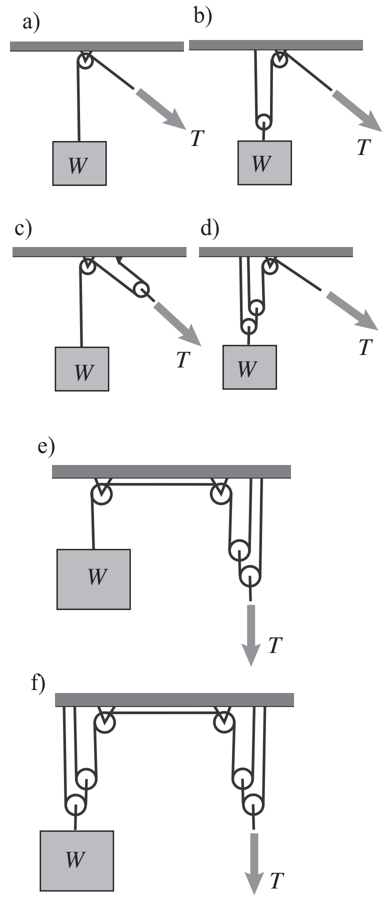


Problem 7.18

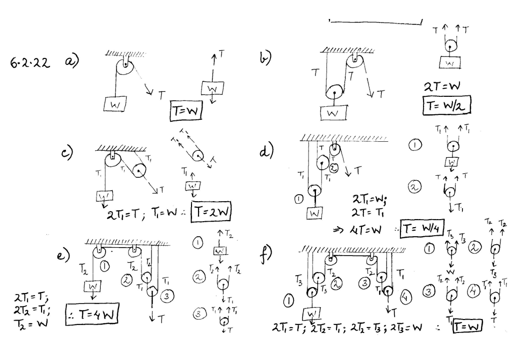
Answer:
200 N

Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

7.2.21 Given W and the frictionless pulleys shown find the tension T needed to lift the weight in the situations shown.

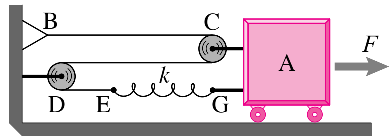


Problem 7.21



Disclaimer: *We have lost track of the many people who wrote these solutions. They are not official and have not been reviewed by the authors for correctness.*

7.2.23 The pulley arrangement shown in the figure uses a spring EG of stiffness $k = 200\,\mathrm{N/cm}$. If the spring is stretched by 1.5 cm under the application of force F for equilibrium, find F.

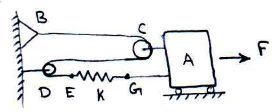


Problem 7.23

6.2.24

Find the force F that causes the spring EG to stretch by 1.5 cm.

Given that $K = 200\ \mathrm{N/cm}$.



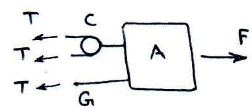
As the spring stretches by 1.5 cm, the tension in the spring is, $T = Kx$

$$\Rightarrow T = 200\ \mathrm{N/cm} \times 1.5\ \mathrm{cm}$$

$$\Rightarrow T = 300\,\mathrm{N}$$

Consider the FBD of the Block A including C and G.

From the FBDs of pulleys C and D, we note that the tension in the string is T.



Applying force balance of the block A.

$$\sum \underline{F} = \underline{0}$$

$$\Rightarrow \left\{ F\hat{\imath} - T\hat{\imath} - 2T\hat{\imath} = \underline{0} \right\}$$

$$\{\ \}\cdot\hat{\imath} \Rightarrow \quad F = 3T$$

$$\therefore \boxed{F = 900\,\mathrm{N}}$$