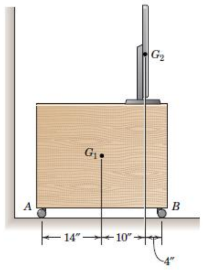
Chapter 3, Problem 1P

Problem

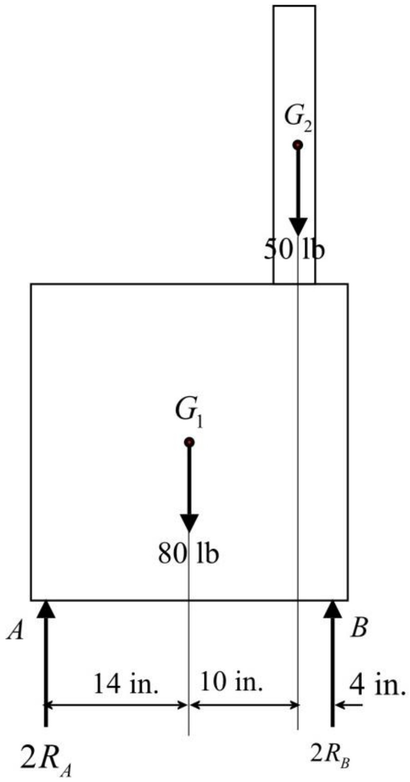
In the side view of a 50-lb flat-screen television resting on an 80-lb cabinet, the respective centers of gravity are labeled $G2$ and $G1$. Assume symmetry into the paper and calculate the normal reaction force at each of the four casters.



Step-by-step solution

Step 1 of 3

Sketch the free body diagram for the system as follows:



The resultant reactions at front and back are $2R_B$ and $2R_A$ respectively as there are two rollers at front and back.

Step 2 of 3

Calculate the moment about point *B*.

$$\sum M_B = 0$$
$$2R_A \times (14+10+4) - 80\times(10+4) - 50\times 4 = 0$$
$$R_A = \frac{80(14)+50\times 4}{2\times(28)}$$
$$= \frac{1320}{56}$$
$$= 23.57\text{ lb}$$

Therefore the normal reaction at point *A* and on the caster beside to point *A* is $\boxed{23.57\text{ lb}}$.

Step 3 of 3

Calculate the moment about point *A*.

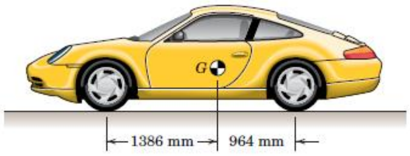
$$\sum M_A = 0$$
$$2R_B \times (4+10+14) - 80\times 14 - 50\times(14+10) = 0$$
$$R_B = \frac{80\times 14 + 50\times 24}{2\times(28)}$$
$$= \frac{2320}{56}$$
$$= 41.43\text{ lb}$$

Therefore the normal reaction at point *B* and on the caster beside to point *B* is $\boxed{41.43\text{ lb}}$.

Chapter 3, Problem 2P

Problem

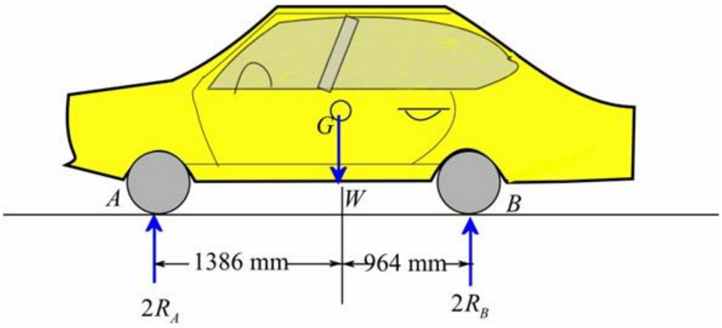
The mass center *G* of the 1400-kg rear-engine car is located as shown in the figure. Determine the normal force under each tire when the car is in equilibrium. State any assumptions.



Step-by-step solution

Step 1 of 3

Draw the free body diagram of the car.



Step 2 of 3

Calculate the weight of the car by using the following relation:

$$W = mg$$

Here, m is the mass of the car and g is the acceleration due to gravity.

Substitute 1400 kg for m and 9.81 m/s^2 for g.

$$\begin{aligned} W &= 1400 \times 9.81 \\ &= 13734 \text{ N} \end{aligned}$$

Consider the moments about point A.

$$\sum M_A = 0$$
$$-W(1386) + 2R_B(1386 + 964) = 0$$

Here, R_B is the normal reaction at one wheel at the rear end.

Substitute 13734 N for W.

$$-13734(1386) + 2R_B(1386 + 964) = 0$$
$$2R_B = 8100.137$$
$$R_B = 4050.07 \text{ N}$$

Therefore, the normal force acting on each back wheel of the car is $\boxed{4050.07 \text{ N}}$.

Step 3 of 3

Consider the moment about the point B.

$$\sum M_B = 0$$
$$-2R_A(964 + 1386) + W(964) = 0$$

Here, R_A is the normal reaction at one wheel at the front end.

Substitute 13734 N for W.

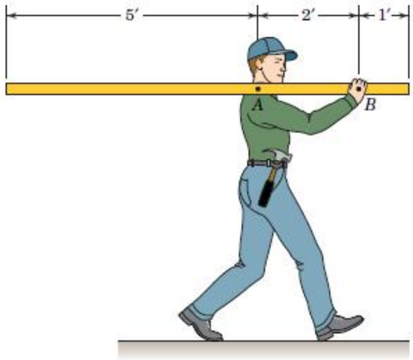
$$\sum M_B = 0$$
$$-2R_A(964 + 1386) + 13734(964) = 0$$
$$R_A = 2816.93 \text{ N}$$

Therefore, the normal force acting on each front wheel of the car is $\boxed{2816.93 \text{ N}}$.

Chapter 3, Problem 3P

Problem

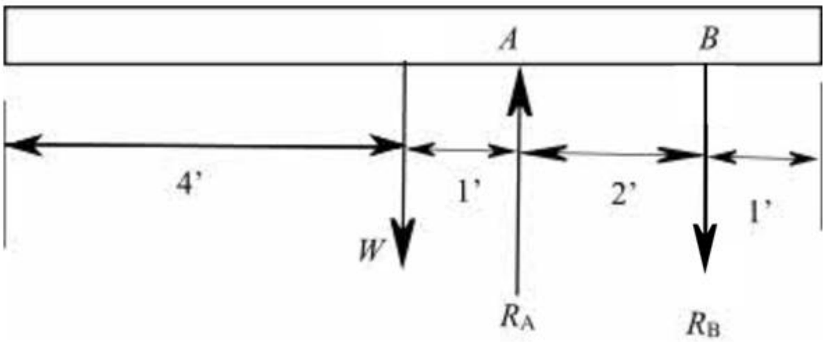
A carpenter carries a 12-lb 2-in. by 4-in. board as shown. What downward force does he feel on his shoulder at *A*?



Step-by-step solution

Step 1 of 2

Draw the free body diagram of the wood board as follows:



Step 2 of 2

Calculate the reaction at *A* as follows:

Take the moments about the point '*B*'.

$$\sum M_B = 0$$

$$W \times (1+2) - R_A \times 2 = 0$$

$$R_A = \frac{3}{2} W$$

Here, *W* is the weight of the wood board and R_A is the reaction at the point *A*.

Substitute 12 lb for *W*.

$$R_A = \frac{3}{2} \times 12$$
$$= 18 \text{ lb}$$

Reaction at *A* is 18 lb.

Therefore, the downward force that the man feels is $\boxed{18 \text{ lb}}$.

Comments (1)

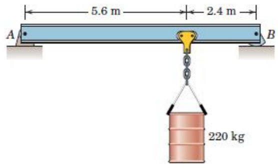
Anonymous

Moment around a to find force of works too, then add it to the -12 lbs.

Chapter 3, Problem 4P

Problem

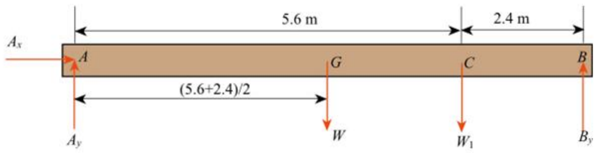
The 450-kg uniform I-beam supports the load shown. Determine the reactions at the supports.



Step-by-step solution

Step 1 of 3

Draw the free body diagram of the beam.



Step 2 of 3

Here, *Ax* is the horizontal component of the reaction at *A*, *Ay* is the vertical component of the reaction at *A*, *By* is the reaction at *B*, *W* is the weight of the beam, and *W*1 is the extra weight.

Apply moment equilibrium about point *A*.

$$\sum M_A = 0;$$

$$B_y(5.6+2.4) - W_1(7.6) - W\left(\frac{5.6+2.4}{2}\right) = 0$$

$$B_y(5.6+2.4) - m_1 g(7.6) - mg\left(\frac{5.6+2.4}{2}\right) = 0$$

Here, *m*1 is the extra mass, *m* is the mass of the beam and *g* is the acceleration due to gravity.

Substitute 220 kg for *m*1, 450 kg for *m* and 9.81 m/s2 for *g*.

$$B_y(5.6+2.4) - (220\times 9.81)(5.6) - (450\times 9.81)\left(\frac{5.6+2.4}{2}\right) = 0$$

$$8B_y - 12085.92 - 17658 = 0$$

$$8B_y = 29743.92$$

$$B_y = 3718\,\text{N}$$

Therefore, the reaction at *B* is $\boxed{3718\,\text{N}}$.

Comments (4)

Anonymous
Where do you get the value '7.6'?

Anonymous
^

Anonymous
must be a typo, he corrects it in the calculations

Anonymous
where did you get the extra weight of 450 from?

Step 3 of 3

Apply force equilibrium equation along vertical direction to find the vertical reaction force at support *A*.

$$\sum F_y = 0;$$

$$A_y + B_y - W_1 - W = 0$$

$$A_y + B_y - m_1 g - mg = 0$$

$$A_y + B_y - (m_1 + m)g = 0$$

Substitute 3718 N for *By*, 220 kg for *m*1, 450 kg for *m* and 9.81 m/s2 for *g*.

$$A_y + 3718 - (220+450)(9.81) = 0$$

$$A_y = 2854.7\,\text{N}$$

Therefore, the vertical reaction force at support *A* is $\boxed{2854.7\,\text{N}}$.

Apply force equilibrium equation along horizontal direction to find the horizontal reaction force at support *A*.

$$\sum F_x = 0;$$

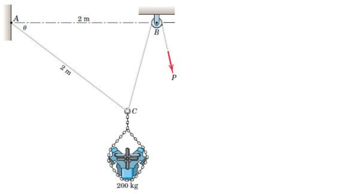
$$A_x = 0$$

Therefore, the horizontal reaction force at support *A* is $\boxed{0}$.

Chapter 3, Problem 5P

Problem

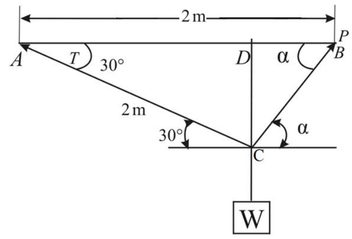
Determine the force P required to maintain the 200-kg engine in the position for which $\theta = 30°$. The diameter of the pulley at B is negligible.



Step-by-step solution

Step 1 of 5

Draw the schematic diagram of engine hanging over the pulley.



Step 2 of 5

Calculate the angle α as follows:

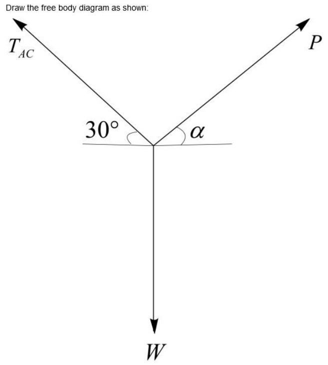
$$\tan\alpha = \frac{CD}{BD}$$
$$\alpha = \tan^{-1}\left(\frac{CD}{AB - AD}\right)$$

Substitute $2\sin 30°\,\text{m}$ for CD, $2\,\text{m}$ for AB, and $2\cos 30°\,\text{m}$ for AD.

$$\alpha = \tan^{-1}\left(\frac{2\sin 30°}{2 - 2\cos 30°}\right) = 75°$$

Step 3 of 5

Draw the free body diagram as shown:



Step 4 of 5

The tension in thread BC is equal to the force P

$$T_{BC} = P$$

Apply force equilibrium equation along the horizontal direction.
$$\Sigma F_x = 0$$
$$-T_{AC}\cos 30° + P\cos\alpha = 0$$

Substitute $75°$ for α.

$$-T_{AC}\cos 30° + P\cos 75° = 0$$
$$P\cos 75° = T_{AC}\cos 30° \quad \text{...... (1)}$$
$$P = \frac{T_{AC}\cos 30°}{\cos 75°}$$

Comments (4)

Anonymous
why the tension in thread BC is equal to the force P ?

Anonymous
It's idealized physics at play here. The easiest way I can explain this is to refer to the fundamentals of physics. No energy can be lost! Since we don't meddle in partial solutions or materialparameters in these books we will always have the full tension in a cable along it's full length.

Anonymous
This is non-intuitive since it is most often not the case. In order for this to be true, the cable and pulleys must be infinitely stiff, massless and frictionless. Also there can't be any vibrations in the system. The cable can be hard to imagine infinitely stiff, but this need to be true in only normal to the cable. It need's to be the opposite in the transversal direction making it infinitely flexible.

Anonymous
lame

Step 5 of 5

Apply force equilibrium equation along the vertical direction.
$$\Sigma F_y = 0$$
$$-W + P\sin\alpha + T_{AC}\sin 30° = 0$$
$$W = P\sin\alpha + T_{AC}\sin 30°$$

Substitute $75°$ for α and $\frac{T_{AC}\cos 30°}{\cos 75°}$ for P.

$$W = \frac{T_{AC}\cos 30°}{\cos 75°} \times \sin 75° + T_{AC}\sin 30°$$

Substitute $(200 \times 9.81)\,\text{N}$ for W.

$$200 \times 9.81 = \frac{T_{AC}\cos 30°}{\cos 75°} \times \sin 75° + T_{AC}\sin 30°$$
$$200 \times 9.81 = T_{AC}\cos 30°\tan 75° + T_{AC}\sin 30°$$
$$200 \times 9.81 = T_{AC}(\cos 30°\tan 75° + \sin 30°)$$
$$T_{AC} = 525.7163\,\text{N}$$

Substitute $525.7163\,\text{N}$ for T_{AC} in equation (1).

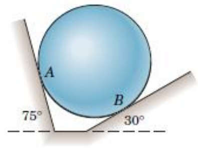
$$P = \frac{525.7163 \times \cos 30°}{\cos 75°} = 1759\,\text{N}$$

Therefore, the force P required to maintain the $200\,\text{kg}$ engine in the position is $\boxed{1759\,\text{N}}$.

Chapter 3, Problem 6P

Problem

The 20-kg homogeneous smooth sphere rests on the two inclines as shown. Determine the contact forces at *A* and *B*.



Step-by-step solution

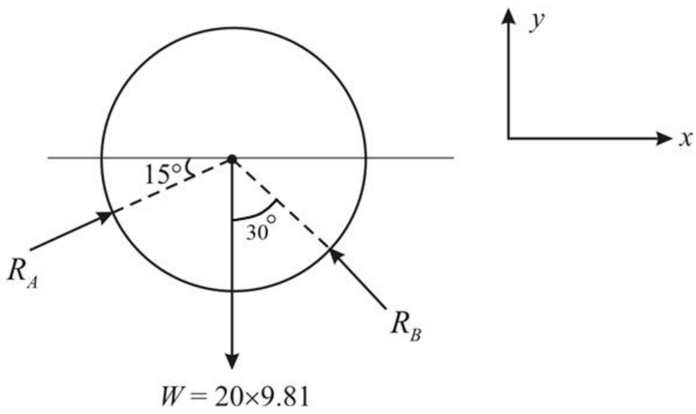
Step 1 of 5

Weight of the sphere $W = 20\times 9.81\,\text{N}$

Let R_A and RB be the reaction A and B respectively

Step 2 of 5

Considering the Free body diagram of the sphere



Step 3 of 5

Considering the forces any $x-\text{direction}$

$\Sigma F_x = 0$

$R_A \cos 15° - R_B \times \sin 30° = 0$

$R_A = R_B \times (\sin 30° / \cos 15°) .... (1)$

Step 4 of 5

Considering the forces any $y-\text{direction}$

$\Sigma F_y = 0$

$R_A \sin 15° + R_B \cos 30° - 20\times 9.81 = 0 .... (2)$

Step 5 of 5

Substituting the value of R_A in the above equation

$R_B\left(\dfrac{\sin 30°}{\cos 15°}\right)\sin 15° + R_B \cos 30° = 20\times 9.81\text{m}$

$\boxed{R_B = 196.2\text{N}}$

Substituting the value of R_B in equation (2)

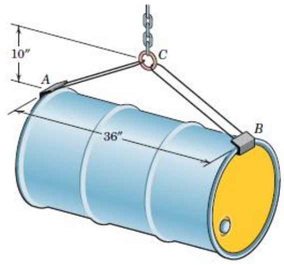
$R_A \sin 15° + 196.2 \cos 30° - 20\times 9.81 = 0$

$\boxed{R_A = 101.56\text{N}}$

Chapter 3, Problem 7P

Problem

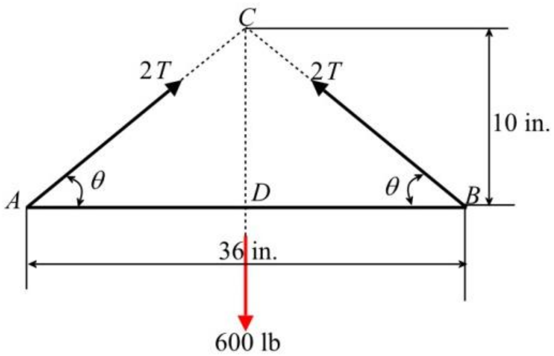
The 600-lb drum is being hoisted by the lifting device which hooks over the end lips of the drum. Determine the tension *T* in each of the equal-length rods which form the two U-shaped members of the device.



Step-by-step solution

Step 1 of 3

Sketch the free body diagram of the drum as follows:



Step 2 of 3

The total tension in each of the U-shaped members at A and B is $2T$.

Step 3 of 3

Obtain the length of *AD* and *AC*.

$$AD = \frac{36}{2} = 18\text{ in.}$$

$$AC = \sqrt{AD^2 + DC^2}$$

Substitute 8 in. for AD, 10 in. for DC.

$$AC = \sqrt{18^2 + 10^2} = 20.59\text{ in.}$$

Find the angle $\sin\theta$ as follows:

$$\sin\theta = \frac{CD}{AC}$$

Substitute 10 in. for CD and 20.59 in. for AC.

$$\sin\theta = \frac{10}{20.59} = 0.4857$$

Determine the tension in each of the equal length rods.

Apply the equilibrium equations as follows:

$$\sum F_y = 0$$

$$2T\sin\theta + 2T\sin\theta - 600 = 0$$

$$T = \frac{600}{4\times\sin\theta}$$

Substitute 0.4857 for $\sin\theta$.

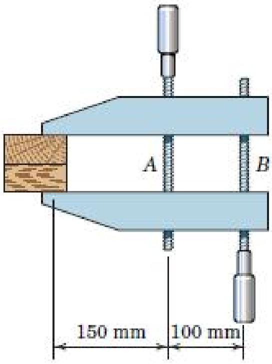
$$T = \frac{600}{4\times 0.4857} = 309\text{ lb}$$

Therefore, the tension T in each of the equal length rods which form the two U-shaped members of the lifting device is $\boxed{309\text{ lb}}$.

Chapter 3, Problem 8P

Problem

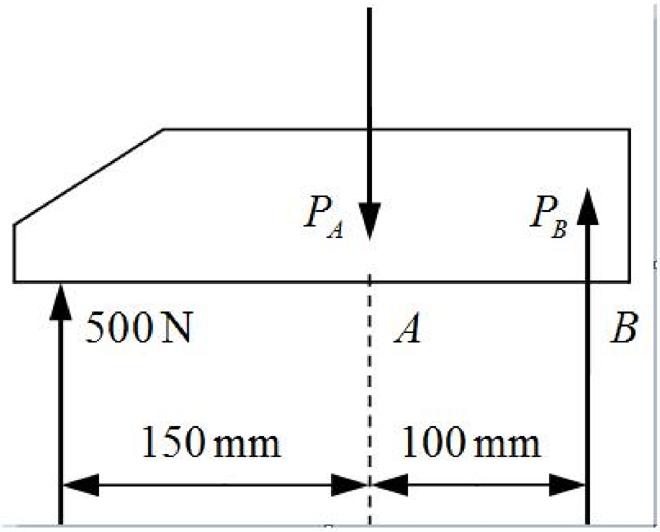
If the screw *B* of the wood clamp is tightened so that the two blocks are under a compression of 500 N, determine the force in screw A. (*Note:* The force supported by each screw may be taken in the direction of the screw.)



Step-by-step solution

Step 1 of 2

Draw the free body diagram of the upper clamp.



Step 2 of 2

Apply the equilibrium condition.

Take moment about *B*.

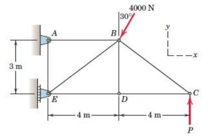
$$\sum M_B = 0$$
$$P_A(100) - 500(150 + 100) = 0$$
$$100P_A - 125000 = 0$$
$$P_A = 1250\text{ N}$$

Therefore, the axial force in screw A is $\boxed{1250\text{ N}}$.

Chapter 3, Problem 9P

Problem

Determine the reactions at *A* and *E* if *P* = 500 N. What is the maximum value which *P* may have for static equilibrium? Neglect the weight of the structure compared with the applied loads.

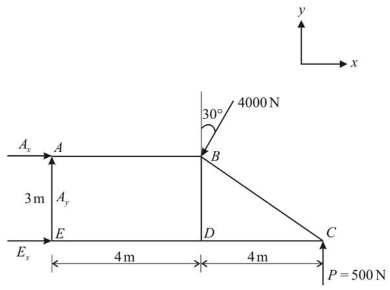


Step-by-step solution

Step 1 of 6

Let A_x, A_y and E_x be the reactions at A and E respectively.

Step 2 of 6



Comments (1)

Anonymous

Why is the Ax force arrow pointing in the positive x-direction shouldn't it be in the negative x-direction?

Step 3 of 6

Taking forces along $x-\text{direction}$

$\sum F_x = 0$

$A_x + E_x - 4000\sin 30° = 0$

$A_x + E_x = 4000\sin 30°$

Taking forces along $y-\text{direction}$

$\sum F_y = 0$

$A_y - 4000\cos 30° + 500 = 0$

$A_y = 4000\cos 30° - 500$

$A_y = 3964.10 - 500$

$\boxed{A_y = 2964.1\,\text{N}}$

Comments (1)

Anonymous

3964.10-500 does NOT equal 2964.1. Please fix

Step 4 of 6

Taking Moments about A

$\sum M_A = 0$

$500 \times 8 + E_x \times 3 - 4000\cos 30° \times 4 = 0$

$3E_x = 16000 \times \cos 30° - 4000$

$E_x = \dfrac{13856.40 - 4000}{3}$

$\boxed{E_x = 3285.46\,\text{N}}$

Step 5 of 6

Substituting the value of E_x is equation (1)

$A_x + 3285.46 - 4000\sin 30° = 0$

$A_x = 4000\sin 30° - 3285.46$

$A_x = 2000 - 3285.46$

$\boxed{A_x = -1285.47\,\text{N}}$

Step 6 of 6

For maximum P

$E_x = 0;$

Moment about A

$\sum M_A = 0$

$P \times 8 - 4000\cos 30° \times 4 = 0$

$8P = 4000\cos 30° \times 4$

$P = \dfrac{13856.40}{8}$

$\boxed{P = 1732.0\,\text{N}}$

Comments (5)

Anonymous

Why is Ex 0 for maximum P?

Anonymous

Yea I don't understand that too

Anonymous

someone needa explain this asap^^

Anonymous

Imagine the reaction force experienced at E, as you increase the force of P, Ex is decreased since P is adding positive moment (CCW). The instant the system will exit equilibrium is when Ex=0, as P has overcome the reaction force at E, and the body will begin to rotate about A.

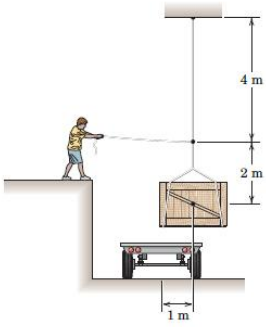
Anonymous

ohh thank you

Chapter 3, Problem 10P

Problem

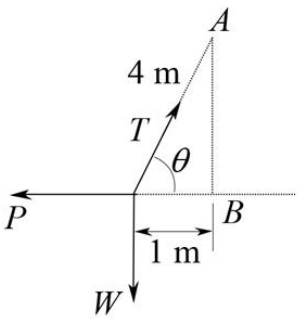
What horizontal force *P* must a worker exert on the rope to position the 50-kg crate directly over the trailer?



Step-by-step solution

Step 1 of 3

Draw the free body diagram.



Step 2 of 3

Calculate the angle θ.

$$\cos\theta = \frac{1}{4}$$
$$\theta = 75.52^\circ$$

Consider the equilibrium equation in horizontal direction.

$$\sum F_x = 0$$
$$P - T\cos\theta = 0$$

Here, *P* is the horizontal force and *T* is the tension developed in the suspension rope.

Substitute 75.52° for θ.

$$P - T\cos 75.52^\circ = 0$$
$$P = 0.25T \quad \text{...... (1)}$$

Step 3 of 3

Consider the equilibrium equation in vertical direction.

$$\sum F_y = 0$$
$$T\sin\theta - W = 0$$
$$T\sin\theta - mg = 0$$

Here, *W* is the weight of the crate, *m* is the mass of the crate and *g* is acceleration due to gravity.

Substitute 50 kg for *m*, 9.81 m/s2 for *g* and 75.52° for θ.

$$T\sin 75.96^\circ - (50)(9.81) = 0$$
$$T\sin 75.52^\circ - 490.5 = 0$$
$$T = 506.6\,\text{N}$$

Substitute $506.6\,\text{N}$ for T in equation (1).

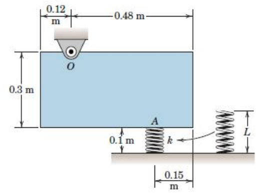
$$\begin{aligned} P &= 0.25T \\ &= 0.25 \times 506.6 \\ &= 126.65\,\text{N} \end{aligned}$$

Therefore the horizontal pulling force exerted by the worker to position the crate is $\boxed{126.65\,\text{N}}$.

Chapter 3, Problem 11P

Problem

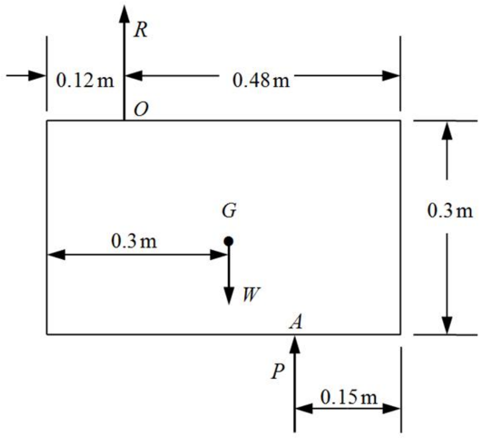
The 20-kg uniform rectangular plate is supported by an ideal pivot at *O* and a spring which must be compressed prior to being slipped into place at point *A*. If the modulus of the spring is *k* = 2 kN/m, what must be its undeformed length *L*?



Step-by-step solution

Step 1 of 4

Draw the free body diagram of the uniform rectangular plate.



Step 2 of 4

Here, R is the reaction force at the pivot O.

Find the distance d of center G from the left hand side of the plate.

$$d=\frac{0.12\,\text{m}+0.48\,\text{m}}{2}$$
$$=\frac{0.6}{2}$$
$$=0.3\text{ m}$$

Calculate the weight of the rectangular plate using the relation:

$$W=mg$$

Here, *m* is the rectangular plate and *g* is the acceleration due to gravity.

Substitute 20 kg for m and 9.81 m/s^2 for g.

$$W=20\,\text{kg}\times 9.81\,\text{m/s}^2$$
$$=196.2\,\text{N}$$

Step 3 of 4

Take moments of forces about point O to determine the spring force P.

$$\Sigma M_o=0$$
$$P\times(0.48-0.15)\text{m}-W\times(0.3-0.12)\text{m}=0$$

Rearrange the relation and simplify it to find P.

$$P=\frac{W\times 0.18\,\text{m}}{0.33\,\text{m}}$$
$$=0.5454W$$

Substitute $196.2\,\text{N}$ for W to obtain P.

$$P=196.2\,\text{N}\times 0.5454$$
$$=107.02\,\text{N}$$

Step 4 of 4

Now determine the deformation δ of the spring using the relation:

$$\delta=\frac{P}{k}$$

Here, *k* is the spring constant.

Substitute $2\,\text{kN/m}$ for k and $107.02\,\text{N}$ for P.

$$\delta=\frac{107.02\,\text{N}}{2\,\text{kN/m}}$$
$$=\frac{107.02\,\text{N}}{2\times 1000\,\text{N/m}}$$
$$=0.0535\,\text{m}$$

Deformed length of the spring is $0.1\,\text{m}$. Determine un-deformed length L of the spring as the summation of deformed length and deformation of the spring.

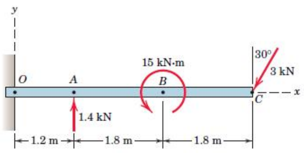
$$L=0.1\,\text{m}+0.0535\,\text{m}$$
$$=0.1535\,\text{m}$$
$$=153.5\text{ mm}$$

Therefore, the un-deformed length of the spring is $\boxed{153.5\,\text{mm}}$.

Chapter 3, Problem 12P

Problem

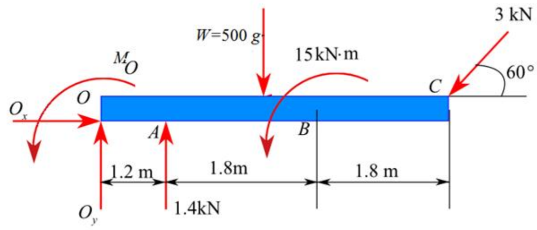
The 500-kg uniform beam is subjected to the three external loads shown. Compute the reactions at the support point *O*. The *x-y* plane is vertical.



Step-by-step solution

Step 1 of 3

The figure shows the cantilever beam with loading.



Comments (3)

Anonymous
why is the moment at O and moment at B the same direction?

Anonymous
Can someone please explain why Ox is in the right direction and not the left?

Anonymous
Forces are equal and opposite. So since Cx is the only point with an x force component and it is going to the left, then Ox has to oppose and go to the right.

Step 2 of 3

Apply equations of equilibrium for the given beam.

$$\sum F_x = 0$$

$$O_x - 3\text{ kN}\cdot\sin(30°) = 0$$

$$O_x = 1500\text{ N}$$

Therefore, the reaction at point *O* in *x* direction is $\boxed{1500\text{ N}}$.

$$\sum F_y = 0$$

$$O_y + 1400 - 500g - 3000\cos(30°) = 0$$

$$O_y + 1400 - 500\times 9.81 - 3000\cos(30°) = 0$$

$$O_y + 1400 - 4905 - 2598.076 = 0$$

$$O_y = 6103.076\text{ N}$$

Therefore, the reaction at point *O* in *y* direction is $\boxed{6103\text{ N}}$.

Step 3 of 3

Take moment about point *O*.

$$\sum M = 0$$

$$M_O + 1400\times 1.2 + 15000 - 500g\times 2.4 - 3000\cos(30°)\times 4.8 = 0$$

$$M_O + 1400\times 1.2 + 15000 - 500\times 9.81\times 2.4 - 3000\cos(30°)\times 4.8 = 0$$

$$M_O + 1680 + 15000 - 11772 - 12470.766 = 0$$

$$M_O = 7562.766\text{ N}\cdot\text{m}$$

Therefore, the moment about point *O* is $\boxed{7563\text{ N}\cdot\text{m}}$.

Comments (5)

Anonymous
where did the 2.4 come from in the last moment equation?

Anonymous
It would help if you answered questions in the comments... I too would like an answer on where "2.4" comes from.

Anonymous
1.2+1.8+1.8= 4.8 , center of mass, in the center, 2.4

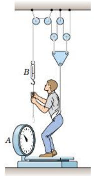
Anonymous
why did you put 500 for mg if your doing it in grams

Anonymous
^ Look closely at what's going on here. The weight of the beam is mass*gravity. g is meant to be acceleration due to gravity, not the units in grams. mass*gravity = (500 kg)(9.81 m/(s^2))

Chapter 3, Problem 13P

Problem

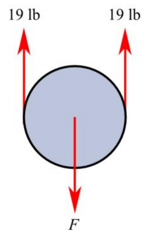
A former student of mechanics wishes to weigh himself but has access only to a scale *A* with capacity limited to 100 lb and a small 20-lb spring dynamometer *B*. With the rig shown he discovers that when he exerts a pull on the rope so that *B* registers 19 lb, the scale *A* reads 67 lb. What is his correct weight?



Step-by-step solution

Step 1 of 6

Show the free body diagram of the pulley as in Figure (1).



Step 2 of 6

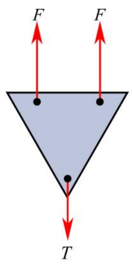
Apply equilibrium condition.

Resolve forces along *y*-axis.

$$\sum F_y = 0$$
$$19 + 19 - F = 0$$
$$F = 38 \text{ lb}$$

Step 3 of 6

Show the free body diagram of the bracket as in Figure (2).



Step 4 of 6

Apply equilibrium condition and resolve forces along *y*-axis.

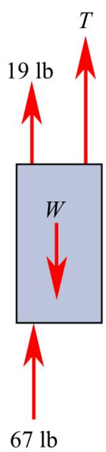
$$\sum F_y = 0$$
$$F + F - T = 0$$
$$2F - T = 0$$

Substitute 38 lb for F.

$$2(38) - T = 0$$
$$T = 76 \text{ lb}$$

Step 5 of 6

Show the free body diagram of the whole system as in Figure (3).



Step 6 of 6

Resolve forces along *y*-axis.

$$\sum F_y = 0$$
$$19 + T + 67 - W = 0$$

Substitute 76 lb for T.

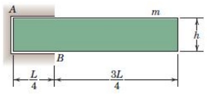
$$19 + 76 + 67 - W = 0$$
$$W = 162 \text{ lb}$$

Therefore, the person weight is $\boxed{162 \text{ lb}}$.

Chapter 3, Problem 14P

Problem

The uniform rectangular body of mass *m* is placed into a fixed opening with slight clearances as shown. Determine the forces at the contact points *A* and *B*. Do your results depend on the height *h*?



Step-by-step solution

Step 1 of 6

When a body under the action of a number of forces is in equilibrium, the resultant force and resultant couple are both zero. Thus algebraic sum of components of the forces along x and y axes as well as algebraic sum of moments of the forces about any point are all zero. Mathematically the relations are expressed as:

$$\Sigma F_x = 0$$

$$\Sigma F_y = 0$$

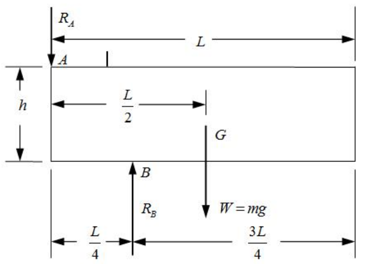
$$\Sigma M = 0$$

Step 2 of 6

Note that the weight W $(=mg)$ of the body acts vertically downwards through its center G which is outside the opening. Due to clearance in the opening, the body will rotate in clock wise direction and will make contacts at points A and B only. The opening will give vertical reactions R_A and R_B at A and B respectively. Draw the free body diagram of the body showing all the forces acting on it as shown below.

Step 3 of 6

Figure depicting the free body diagram of the uniform rectangular plate.



Step 4 of 6

Find the distance d of center G from the left hand side of the body.

$$d = \frac{\frac{L}{4} + \frac{3L}{4}}{2}$$

$$= \frac{L}{2}$$

Note that the weight W is given by $W = mg$, where mass of the body is m and acceleration due to gravity is g.

Apply the equilibrium equation $\Sigma M = 0$ to determine the reactions R_A and R_B.

Equate sum of moments of forces about point B to zero $[\Sigma M_B = 0]$.

$$R_A \times \frac{L}{4} - mg \times \left(\frac{L}{2} - \frac{L}{4}\right) = 0 \text{ ...... (1)}$$

Step 5 of 6

Rearrange equation (1) and simplify it to find R_A.

$$R_A = \frac{mg \times \left(\frac{L}{2} - \frac{L}{4}\right)}{\frac{L}{4}}$$

$$= \frac{mg\left(\frac{L}{4}\right)}{\frac{L}{4}}$$

$$= mg$$

Therefore the reaction force at point A is $\boxed{mg}$.

Step 6 of 6

Equate sum of moments of forces about point A to zero $[\Sigma M_A = 0]$.

$$R_B \times \frac{L}{4} - mg \times \frac{L}{2} = 0$$

Rearrange and simplify the relation to find R_B.

$$R_B = \frac{mg \times \left(\frac{L}{2}\right)}{\frac{L}{4}}$$

$$= 2mg$$

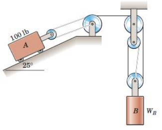
Therefore the reaction force at point B is $\boxed{2mg}$.

To find the moments, only horizontal distances were required as the forces are vertical. So the results are independent of height h.

Chapter 3, Problem 15P

Problem

What weight *WB* will cause the system to be in equilibrium? Neglect all friction, and state any other assumptions.



Step-by-step solution

Step 1 of 7

When a body under the action of a number of forces is in equilibrium, the resultant force and resultant couple are both zero. Thus algebraic sum of components of the forces along x and y axes as well as algebraic sum of moments of the forces about any point are all zero. Mathematically the relations are expressed as:

$\Sigma F_x = 0$
$\Sigma F_y = 0$
$\Sigma M = 0$

Step 2 of 7

Assume the following conditions:

(1) Each pulley is free to rotate about its bearing,

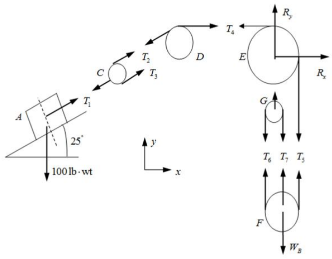
(2) Weights of all parts are small compared to the load,

(3) All the three ropes supporting the load W_B are vertical.

Draw the free-body diagram of the load A. Name the pulleys from the side of load A as C, D, E, F and G in order. Draw free-body diagram of each pulley in its position relative to others as shown in figure. Start from the side of load A. Take tensions in connecting rods and ropes as shown.

Step 3 of 7

Figure depicting the free body diagram of the weights and pulley system.



First consider the free-body diagram of block A. Equate the sum of forces along the inclined plane to zero.

$T_1 - 100\,\text{lb} \times \sin 25° = 0$
$T_1 = 100\,\text{lb} \times \sin 25°$
$T_1 = 42.26\,\text{lb}$

Consider free-body diagram of pulley C of radius r_C and calculate the equilibrium of moments $[\Sigma M = 0]$ about its center.

$T_2 \times r_C - T_3 \times r_C = 0$
$T_2 = T_3$

Comments (2)

Anonymous
Why not add up the forces in an axis? Why not T1sin25-100=0?

Anonymous
He rotated the axis

Step 4 of 7

Take equilibrium of forces along the inclined plane.

$T_2 + T_3 = T_1$

Substitute T_2 for T_3 and $42.26\,\text{lb}$ for T_1.

$T_2 = \dfrac{42.26\,\text{lb}}{2}$

$T_2 = 21.13\,\text{lb}$ ...... (1)

Consider free-body diagram of pulley D of radius r_D and calculate the equilibrium of moments $[\Sigma M = 0]$ about its center.

$T_2 \times r_D - T_4 \times r_D = 0$
$T_4 = T_2$

Using equation (1) the value of tension T_4 is,

$T_4 = 21.13\,\text{lb}$ ...... (2)

Step 5 of 7

Consider free-body diagram of pulley E of radius r_E and calculate the equilibrium of moments $[\Sigma M = 0]$ about its center.

$T_5 \times r_E - T_4 \times r_E = 0$
$T_5 = T_4$

Using equation (2) the value of tension T_5 is,

$T_5 = 21.13\,\text{lb}$ ...... (3)

Consider free-body diagram of pulley G of radius r_G and calculate the equilibrium of moments $[\Sigma M = 0]$ about its center.

$T_6 \times r_G - T_7 \times r_G = 0$
$T_6 = T_7$ ...... (4)

Step 6 of 7

Consider free-body diagram of pulley F of radius r_F and calculate the equilibrium of moments $[\Sigma M = 0]$ about its center.

$T_5 \times r_F - T_6 \times r_F = 0$
$T_5 = T_6$

Using equation (3) the value of tension T_6 is,

$T_6 = 21.13\,\text{lb}$

Now use equation (4) to determine the value of tension T_7.

$T_7 = 21.13\,\text{lb}$

Step 7 of 7

Consider equilibrium of forces along the vertical direction $[\Sigma F_y = 0]$.

$W_B - T_5 - T_6 - T_7 = 0$
$W_B = T_5 + T_6 + T_7$

Substitute $21.13\,\text{lb}$ for T_5, T_6 and T_7.

$$\begin{aligned} W_B &= 21.13\,\text{lb} + 21.13\,\text{lb} + 21.13\,\text{lb} \\ &= 63.39\,\text{lb} \\ &\simeq 63.4\,\text{lb} \end{aligned}$$

Therefore the weight W_B required to keep the system in equilibrium is $\boxed{63.4\,\text{lb}}$.

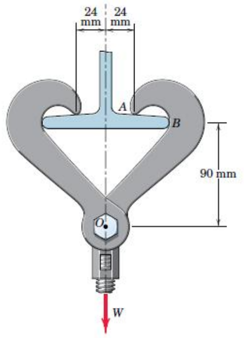
Comments (1)

Anonymous
this problem is a big downvote for me

Chapter 3, Problem 16P

Problem

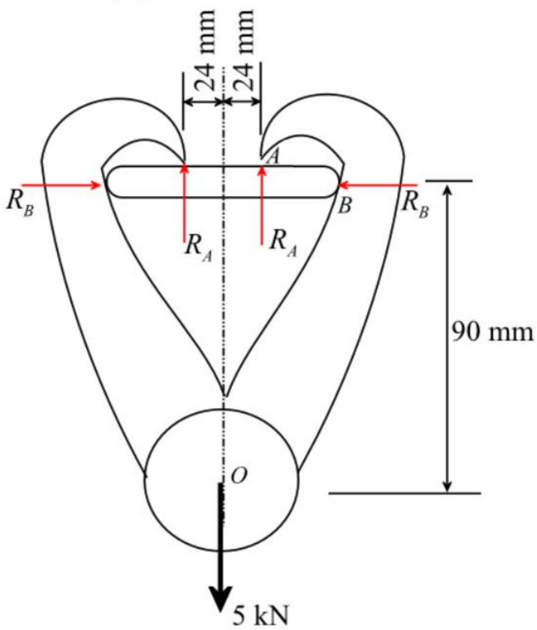
The pair of hooks is designed for the hanging of loads from horizontal I-beams. If the load $W = 5$ kN, estimate the contact forces at *A* and *B*. Neglect all friction.



Step-by-step solution

Step 1 of 3

Draw the free body diagram as follows:



Step 2 of 3

Consider the vertical force equilibrium condition:

$$\Sigma F_y = 0$$
$$R_A + R_B - 5 = 0$$
$$2R_A = 5$$
$$R_A = 2.5 \text{ kN}$$

Here, R_A is the contact force at *A*.

Therefore, the contact force at *A* is $\boxed{2.5 \text{ kN}}$.

Step 3 of 3

Consider the moment equilibrium condition about *O*.

$$\Sigma M_O = 0$$
$$R_B(90) - R_A(24) = 0$$

Here, R_B is the contact force at *B*.

Substitute 2.5 kN for R_A.

$$R_B(90) - 2.5(24) = 0$$
$$R_B = 0.667 \text{ kN}$$

Therefore, the contact force at *B* is $\boxed{0.667 \text{ kN}}$.

Comments (1)

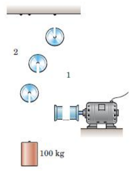
Anonymous

why do you take into account only one of the each forces when calculating moment and not all of them?

Chapter 3, Problem 17P

Problem

The winch takes in cable at the constant rate of 200 mm/s. If the cylinder mass is 100 kg, determine the tension in cable 1. Neglect all friction.



Step-by-step solution

Step 1 of 6

When a body under the action of a number of forces is in equilibrium, the resultant force and resultant couple are both zero. Thus algebraic sum of components of the forces along x and y axes as well as algebraic sum of moments of the forces about any point are all zero. Mathematically the relations are expressed as:

$\sum F_x = 0$

$\sum F_y = 0$

$\sum M = 0$

Assume the following conditions:

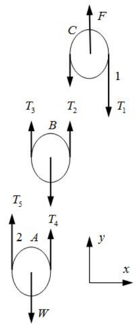
(1) Each pulley is free to rotate about its bearing and

(2) Weights of all parts are small compared to the load.

Name the pulleys from the side of load as A, B and C in order. Take radius of each pulley as r. Draw free-body diagram of each pulley in its position relative to others as shown in figure. Start from the pulley A from the side of load. Take tensions in ropes as shown. As the cylinder has no acceleration, Tensions are only to support the load.

Step 2 of 6

Figure depicting the free body diagram of the weights and pulley system.



Step 3 of 6

Calculate the weight using the relation:

$W = mg$

Substitute 100 kg for m and 9.81 m/s^2 for g.

$$W = 100\text{kg} \times 9.81\text{m/s}^2 = 981\text{ N}$$

Consider free-body diagram of pulley A of radius r and calculate the equilibrium of moments $[\sum M = 0]$ about its center.

$T_4 \times r - T_5 \times r = 0$

$T_4 = T_5$ ...... (1)

Step 4 of 6

Consider the equilibrium of forces along y-axis $[\sum F_y = 0]$.

$T_4 + T_5 - W = 0$

Using equation (1), substitute T_4 for T_5.

$$T_4 + T_4 - W = 0$$
$$2T_4 - W = 0$$
$$T_4 = \frac{W}{2}$$

Consider free-body diagram of pulley B of radius r and calculate the equilibrium of moments $[\sum M = 0]$ about its center.

$T_2 \times r - T_3 \times r = 0$

$T_2 = T_3$ ...... (2)

Step 5 of 6

Take equilibrium of forces along y-axis $[\sum F_y = 0]$.

$T_2 + T_3 - T_4 = 0$

Substitute T_2 for T_3 from equation (2) and $W/2$ for T_4.

$$T_2 + T_2 - \frac{W}{2} = 0$$
$$2T_2 - \frac{W}{2} = 0$$
$$T_2 = \frac{W}{4} \text{ ...... (3)}$$

Consider free-body diagram of pulley C of radius r and calculate the equilibrium of moments $[\sum M = 0]$ about its center.

$T_1 \times r - T_2 \times r = 0$

$T_1 = T_2$

Step 6 of 6

Using equation (3) the value of tension T_1 is,

$$T_1 = T_2 = \frac{W}{4}$$

Substitute 981N for W.

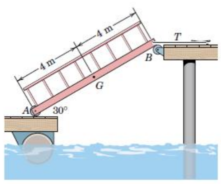
$$T_1 = \frac{981\text{N}}{4}$$
$$T_1 = 245.25\text{N}$$

Therefore the tension in the cable 1 is $\boxed{245.25\text{N}}$.

Chapter 3, Problem 18P

Problem

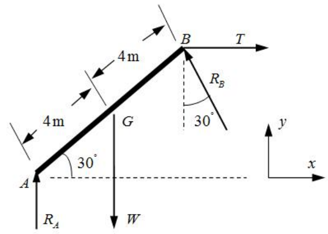
To accommodate the rise and fall of the tide, a walkway from a pier to a float is supported by two rollers as shown. If the mass center of the 300-kg walkway is at *G*, calculate the tension *T* in the horizontal cable which is attached to the cleat and find the force under the roller at *A*.



Step-by-step solution

Step 1 of 5

Draw the free-body diagram of the walk way showing all the forces acting on it.



Step 2 of 5

Note that the reaction force R_A at A applied by the float to the walk way is acting vertically upwards. The weight W of the walk way is acting vertically downwards at the point G. The reaction force R_B on the walk way by the roller at B is perpendicular to the walk way in upward direction. Consider T as the tension in the horizontal cable at B.

Determine the weight W of the walk way.

$$W = 300\,\text{kg} \times 9.81\,\text{m/s}^2$$
$$= 2943\,\text{N}$$

Step 3 of 5

Apply equilibrium of moments to determine the reaction force R_A.

$$\Sigma M_B = 0$$
$$\{R_A \times (4+4)\,\text{m} \times \cos 30°\} - (W \times 4\,\text{m} \times \cos 30°) = 0$$

Rearrange and simplify to determine the reaction force R_A.

$$R_A = \frac{W \times 4\,\text{m}}{8\,\text{m}}$$
$$= \frac{W}{2}$$

Substitute $2943\,\text{N}$ for W.

$$R_A = \frac{2943\,\text{N}}{2}$$
$$= 1471.5\,\text{N}$$

Therefore, the force under the roller at A is $\boxed{1471.5\,\text{N}}$.

Step 4 of 5

Consider the equilibrium of forces along *x* direction.

$$\Sigma F_x = 0$$
$$T - R_B \sin 30° = 0$$
$$T = R_B \sin 30° \quad \text{...... (1)}$$

Consider the equilibrium of forces along *y* direction.

$$\Sigma F_y = 0$$
$$R_A + R_B \cos 30° - W = 0$$
$$W - R_A = R_B \cos 30° \quad \text{...... (2)}$$

Comments (1)

Anonymous
You could just find Rb by: (W-Ra)/cos30

Step 5 of 5

Divide equation (1) by equation (2) and rearrange the relation in terms of T.

$$\frac{T}{W - R_A} = \frac{R_B \sin 30°}{R_B \cos 30°}$$
$$\frac{T}{W - R_A} = \tan 30°$$
$$T = (W - R_A)\tan 30° \quad \text{...... (3)}$$

Substitute $2943\,\text{N}$ for *W*, $1471.5\,\text{N}$ for R_A, and 0.57735 for $\tan 30°$ to obtain T.

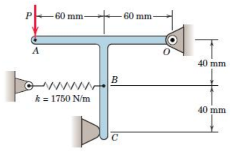
$$T = (2943 - 1471.5)\,\text{N} \times 0.57735$$
$$= 1471.5 \times 0.57735$$
$$= 849.57\,\text{N}$$

Therefore, the tension in the horizontal cable attached to the cleat is $\boxed{849.57\,\text{N}}$.

Chapter 3, Problem 19P

Problem

When the 0.05-kg body is in the position shown, the linear spring is stretched 10 mm. Determine the force *P* required to break contact at *C*. Complete solutions for (*a*) including the effect of the weight and (*b*) neglecting the weight.

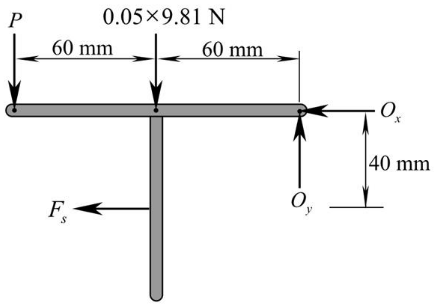


Step-by-step solution

Step 1 of 5

a)

Draw the free body diagram of the bar including the effect for the weight of the bar.



Comments (2)

Anonymous
Why is resultant force from point C not considered?

Anonymous
Because it is not attached to a support system. It is merely resting on it

Step 2 of 5

Apply equilibrium condition.

Take moment about *O*.

$$\sum M_O = 0$$
$$P(120) + (0.05\times 9.81\times 60) - F_s(40) = 0 \quad \text{...... (1)}$$

Here, F_s is the spring force.

Calculate the spring force.

$$F_s = kx$$

Here, *k* is the spring constant and *x* is the stretched length of the spring.

Substitute 1750 N/m for k and 0.01 m for x.

$$F_s = (1750)(0.01) = 17.5\text{ N}$$

Substitute 17.5 N for F_s in equation (1).

$$P(120) + (0.05\times 9.81\times 60) - 17.5(40) = 0$$
$$P = 5.59\text{ N}$$

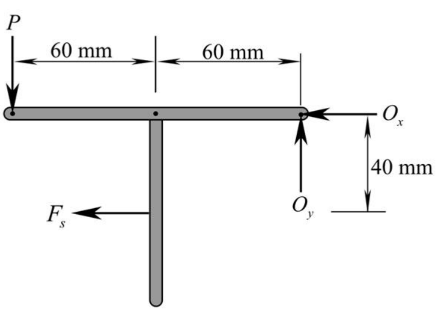
Therefore, the load when the weight is included is $\boxed{5.59\text{ N}}$.

Step 3 of 5

b)

Draw the free body diagram of the bar neglecting the effect for the weight of the bar.

Step 4 of 5



Step 5 of 5

Apply equilibrium condition.

Take moment about *O*.

$$\sum M_O = 0$$
$$P(120) - F_s(40) = 0$$

Substitute 17.5 N for F_s.

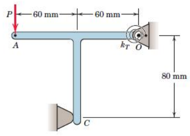
$$120P - 17.5(40) = 0$$
$$P = 5.83\text{ N}$$

Therefore, the load when the weight is not included is $\boxed{5.83\text{ N}}$.

Chapter 3, Problem 20P

Problem

When the 0.05-kg body is in the position shown, the torsional spring at *O* is pretensioned so as to exert a 0.75-N · m clockwise moment on the body. Determine the force *P* required to break contact at *C*. Complete solutions for (*a*) including the effect of the weight and (*b*) neglecting the weight.



Step-by-step solution

Step 1 of 6

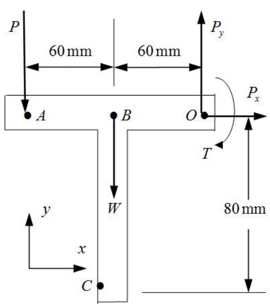
Note that the reaction force on the body at contact point C will be zero as soon as the contact is broken. The weight W of the body is acting vertically downwards through the mid-point B. The torsional spring applies a clock wise moment T at hinge point O on the body. Take the horizontal and vertical reactions on the body at hinge O as P_x and P_y respectively.

Step 2 of 6

(a) Considering effect of weight of the body :

Draw the free-body diagram of the body showing all the forces acting on it as given below. Note that force at C is zero.

Step 3 of 6



Step 4 of 6

Find the weight W of the body.

$$W = 0.05\,\text{kg} \times 9.81\,\text{m/s}^2$$
$$= 0.4905\,\text{N}$$

Apply equilibrium of moments.

$$\sum M_O = 0$$
$$\left[P \times (60+60)\,\text{mm}\right] + (W \times 60\,\text{mm}) - T = 0$$
$$120P = T - W60$$
$$P = \frac{T - W60}{120}$$

Substitute $0.4905\,\text{N}$ for W and $0.75 \times 10^3\,\text{N}\cdot\text{mm}$ for T to find P. Thus

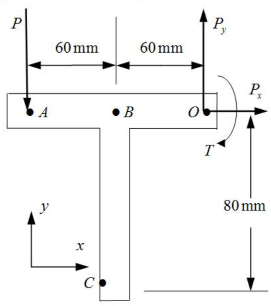
$$P = \frac{T - W60}{120}$$
$$= \frac{(0.75 \times 10^3) - (60 \times 0.4905)}{120}$$
$$= \frac{750 - 29.43}{120}$$
$$= 6.005\,\text{N}$$

Thus, the force P required to break contact of the body at C is $\boxed{6.005\,\text{N}}$ when the effect of weight is considered.

Step 5 of 6

(b) Neglecting effect of weight of the body:

Draw the free-body diagram of the body showing all the forces acting on it except W as given below. Note that force at C is zero.



Apply equilibrium of moments.

$$\sum M_O = 0$$
$$\left[P \times (60+60)\,\text{mm}\right] - T = 0$$
$$120P = T$$
$$P = \frac{T}{120}$$

Step 6 of 6

Substitute $0.75 \times 10^3\,\text{N}\cdot\text{mm}$ for T to find P.

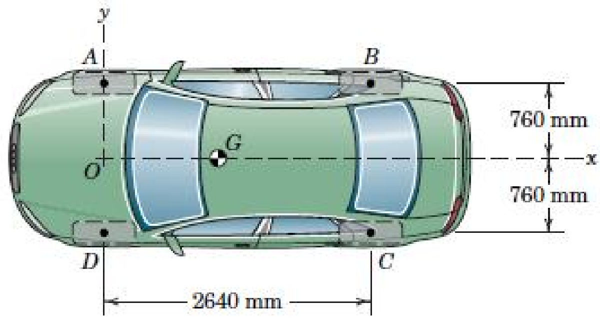
$$P = \frac{0.75 \times 10^3\,\text{N}\cdot\text{mm}}{120\,\text{mm}}$$
$$= \frac{750\,\text{N}\cdot\text{mm}}{120\,\text{mm}}$$
$$= 6.25\,\text{N}$$

Thus, the force P required to break contact of the body at C is $\boxed{6.25\,\text{N}}$ when the effect of weight is neglected.

Chapter 3, Problem 21P

Problem

When on level ground, the car is placed on four individual scales—one under each tire. The scale readings are 4450 N at each front wheel and 2950 N at each rear wheel. Determine the x-coordinate of the mass center *G* and the mass of the car.



Step-by-step solution

Step 1 of 2

Calculate the mass of the car by apply equilibrium condition.

Resolve the forces along *y*-axis.

$$\sum F_y = 0$$
$$2(4450)+2(2950)-mg=0$$

Substitute $9.81\,\text{m/s}^2$ for g.

$$2(4450)+2(2950)-m(9.81)=0$$
$$m=1508.66\,\text{kg}$$

Therefore, the mass of the car is $\boxed{1508.66\,\text{kg}}$.

Step 2 of 2

Take moment about the center of gravity.

$$\sum M_O = 0$$
$$2(2950)(2640)-mg(x)=0$$

Substitute $9.81\,\text{m/s}^2$ for g and $1508.66\,\text{kg}$ for m.

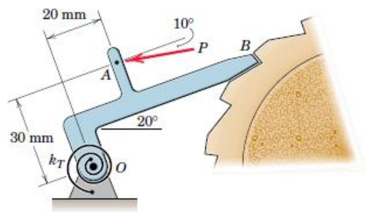
$$2(2950)(2640)-(1508.66\times 9.81)(x)=0$$
$$15576000-14799.9546(x)=0$$
$$x=1052.44\,\text{mm}$$

Therefore, the *x*-coordinate of the mass center is $\boxed{1052.44\,\text{mm}}$.

Chapter 3, Problem 22P

Problem

Determine the magnitude *P* of the force required to rotate the release pawl *OB* counterclockwise from its locked position. The torsional spring constant is *kT* = 3.4 N · m/rad and the pawl end of the spring has been deflected 25° counterclockwise from the neutral position in the configuration shown. Neglect any forces at the contact point *B*.

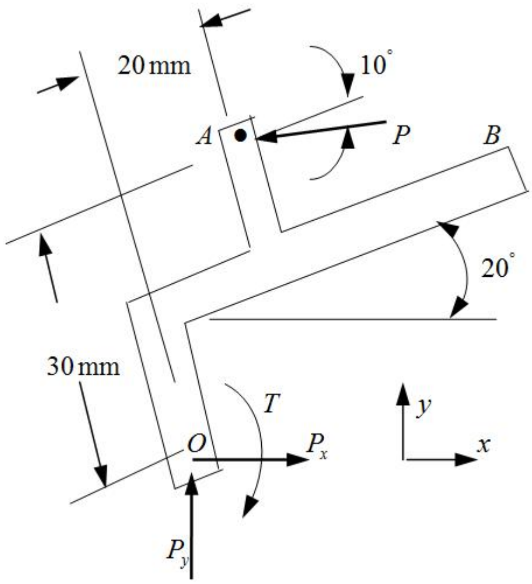


Step-by-step solution

Step 1 of 1

Note that the reaction force on the pawl at contact point B is zero. The torsion spring applies a clock wise moment T at hinge point O. Take the horizontal and vertical reactions on the pawl at hinge O as P_x and P_y respectively. Draw the free-body diagram of the pawl showing all the forces acting on it as given below.

Draw the free body diagram of the pawl.



Write the moment expression applied on the pawl.

$T = k_T \times \theta$ ...... (1)

Here, k_T is torsional spring constant and deflection angle of spring is θ radian. Substitute $3.4\,\mathrm{N\cdot m}$ for k_T and $\frac{25^\circ \times \pi}{180^\circ}$ for θ in equation (1) to find T.

$$\begin{aligned} T &= 3.4\,\mathrm{N\cdot m} \times \frac{25^\circ \times \pi}{180^\circ} \\ &= 1.484\,\mathrm{N\cdot m} \\ &= 1484.13\,\mathrm{N\cdot mm} \end{aligned}$$

Apply equilibrium of moment about point *O*.

$$\sum M_O = 0$$

$$\left(P\cos 10^\circ \times 30\,\mathrm{mm}\right) + \left(P\sin 10^\circ \times 20\,\mathrm{mm}\right) - T = 0$$

$$P\left(30\cos 10^\circ + 20\sin 10^\circ\right) = T$$

$$P = \frac{T}{30\cos 10^\circ + 20\sin 10^\circ}$$

Substitute $1484.13\,\mathrm{N\cdot mm}$ for T.

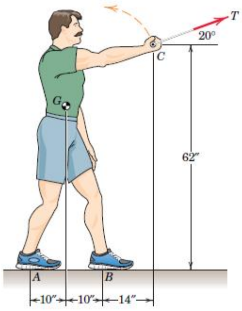
$$\begin{aligned} P &= \frac{1484.13}{(0.98481 \times 30) + (0.17365 \times 20)} \\ &= 44.95\,\mathrm{N} \end{aligned}$$

Thus, the force P required to rotate the release pawl counter clock wise from its locked position under the given condition is $\boxed{44.95\,\mathrm{N}}$.

Chapter 3, Problem 23P

Problem

The 180-lb exerciser is beginning to execute some slow, steady bicep curls. As the tension T = 15 lb is developed against an exercise machine (not shown), determine the normal reaction forces at the feet A and B. Friction is sufficient to prevent slipping, and the exerciser maintains the position shown with center of gravity at G.

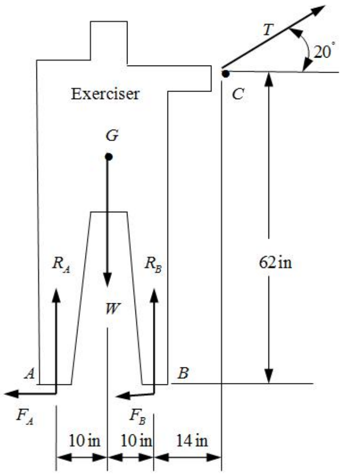


Step-by-step solution

Step 1 of 2

Consider the normal reaction forces at the feet A and B as R_A and R_B respectively. Take the friction forces at A and B as F_A and F_B respectively.

Draw free-body diagram of the exerciser.



Apply equilibrium condition of moment about point A.

$$\sum M_A = 0$$
$$\left(R_B \times (10+10)\right) - (W \times 10) - (T\cos 20° \times 62) + (T \sin 20° \times 34) = 0$$
$$20R_B - 10W - 58.26T + 11.63T = 0$$
$$R_B = \frac{10W + 46.63T}{20}$$

Substitute $180\,\text{lb}$ for W and $15\,\text{lb}$ for T.

$$R_B = \frac{(10\times 180) + (46.63 \times 15)}{20}$$
$$= 124.97\,\text{lb}$$

Therefore, the reaction force at foot B is as $\boxed{124.97\,\text{lb}\cdot\text{wt}}$.

Step 2 of 2

Apply equilibrium condition of moment.

$$\sum M_B = 0$$
$$-\left((10+10)\times R_A\right) + (W \times 10) - (T\cos 20° \times 62) + (T\sin 20° \times 14) = 0$$
$$20R_A = 10W - 53.47T$$
$$R_A = \frac{10W - 53.47T}{20}$$

Substitute $180\,\text{lb}$ for W and $15\,\text{lb}$ for T.

$$R_A = \frac{(10\times 180) - (53.47 \times 15)}{20}$$
$$= 49.895\,\text{lb}\cdot\text{wt}$$

Therefore, the reaction force at foot A is as $\boxed{49.895\,\text{lb}}$.

Comments (2)

Anonymous

wouldnt Ra = Rb due to symmetry??

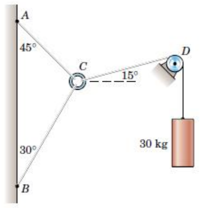
Anonymous

It's not symmetrical - would only be symmetrical if C would be in line with G

Chapter 3, Problem 24P

Problem

Three cables are joined at the junction ring *C*. Determine the tensions in cables *AC* and *BC* caused by the weight of the 30-kg cylinder.



Step-by-step solution

Step 1 of 5

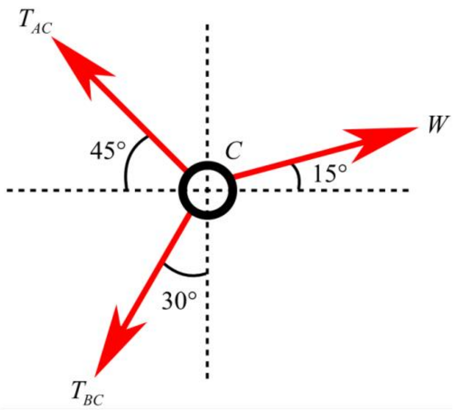
As the pulley at *D* is frictionless, tension in cable *CD* is equal to the weight of the cylinder.

$T_{CD} = W$

Here, the tension in cable *CD* is T_{CD} and the weight of the cylinder is *W*.

Step 2 of 5

Draw the free body diagram of the ring *C*.



Step 3 of 5

Apply the force equilibrium equation along *y*-axis.

$$\sum F_y = 0$$
$$W \sin 15° + T_{AC} \sin 45° - T_{BC} \cos 30° = 0$$
$$(mg)\sin 15° + 0.707T_{AC} - 0.866T_{BC} = 0$$

Here, the tension in cable *AC* is T_{AC} and the tension in cable *BC* is T_{BC}.

Substitute 30 kg for m and 9.81 m/s^2 for g.

$$(30\times 9.81)\sin 15° + 0.707T_{AC} - 0.866T_{BC} = 0$$
$$76.17 + 0.707T_{AC} - 0.866T_{BC} = 0$$
$$0.707T_{AC} - 0.866T_{BC} = -76.17$$
$$0.707T_{AC} = 0.866T_{BC} - 76.17$$
$$T_{AC} = 1.225T_{BC} - 107.74 \quad \text{...... (1)}$$

Step 4 of 5

Apply the force equilibrium equation along *x*-axis.

$$\sum F_x = 0$$
$$W \cos 15° - T_{AC} \cos 45° - T_{BC} \sin 30° = 0$$
$$(mg)\cos 15° - 0.707T_{AC} - 0.5T_{BC} = 0$$

Substitute $[1.225T_{BC} - 107.74]$ for T_{AC}, 30 kg for m, and 9.81 m/s^2 for g.

$$(30\times 9.81)\cos 15° - 0.707[1.225T_{BC} - 107.74] - 0.5T_{BC} = 0$$
$$284.27 - 0.866T_{BC} + 76.17 - 0.5T_{BC} = 0$$
$$1.366T_{BC} = 360.44$$
$$T_{BC} = 263.86 \text{ N}$$

Therefore, the tension in cable *BC* is $\boxed{263.86 \text{ N}}$.

Step 5 of 5

Calculate the tension in cable *AC* by substituting 263.86 N for T_{BC} in equation (1).

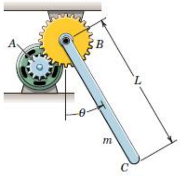
$$T_{AC} = 1.225T_{BC} - 107.74$$
$$= 1.225(263.86) - 107.74$$
$$= 215.48 \text{ N}$$

Therefore, the tension in the cable *AC* is $\boxed{215.48 \text{ N}}$.

Chapter 3, Problem 25P

Problem

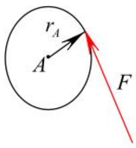
Determine the moment *M* which the motor must exert in order to position the uniform slender bar of mass *m* and length *L* in the arbitrary position *θ*. The ratio of the radius of the gear wheel *B* attached to the bar to that of the gear wheel *A* attached to the motor shaft is 2.



Step-by-step solution

Step 1 of 4

Draw free body diagram of gear *A*.



Here, F is the force exerted at mating point and r_A is the radius of gear *A*.

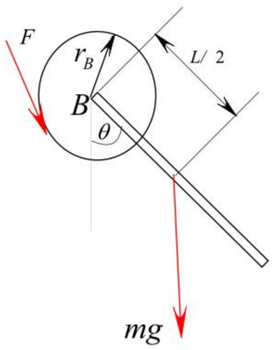
Step 2 of 4

Take moment about point *A*,

$$M = F \times r_A$$
$$F = \frac{M}{r_A}$$

Step 3 of 4

Draw free body diagram of slender rod and gear *B*.



Step 4 of 4

Take moment about point *B*,

$$\Sigma M_B = 0$$
$$F \times r_B - mg \times \frac{L}{2}\sin\theta = 0$$

Here, r_B is radius of gear *B*, *m* is the mass of slender rod, *L* is length of the slender rod.

Substitute $\frac{M}{r_A}$ for *F*.

$$F \times r_B - mg \times \frac{L}{2}\sin\theta = 0$$
$$\frac{M}{r_A} \times r_B - mg \times \frac{L}{2}\sin\theta = 0$$
$$M \times \frac{r_B}{r_A} = mg \times \frac{L}{2}\sin\theta$$

Since the ratio of radii of gear *B* to gear *A* is 2, substitute 2 for $\frac{r_B}{r_A}$.

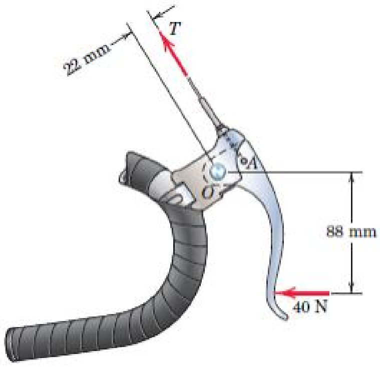
$$M \times 2 = mg \times \frac{L}{2}\sin\theta$$
$$M = \frac{mgL}{4}\sin\theta$$

Thus, the moment at which the motor must exert on gear wheel A to keep the bar in arbitrary position θ is $\boxed{\frac{mgL\sin\theta}{4}}$.

Chapter 3, Problem 26P

Problem

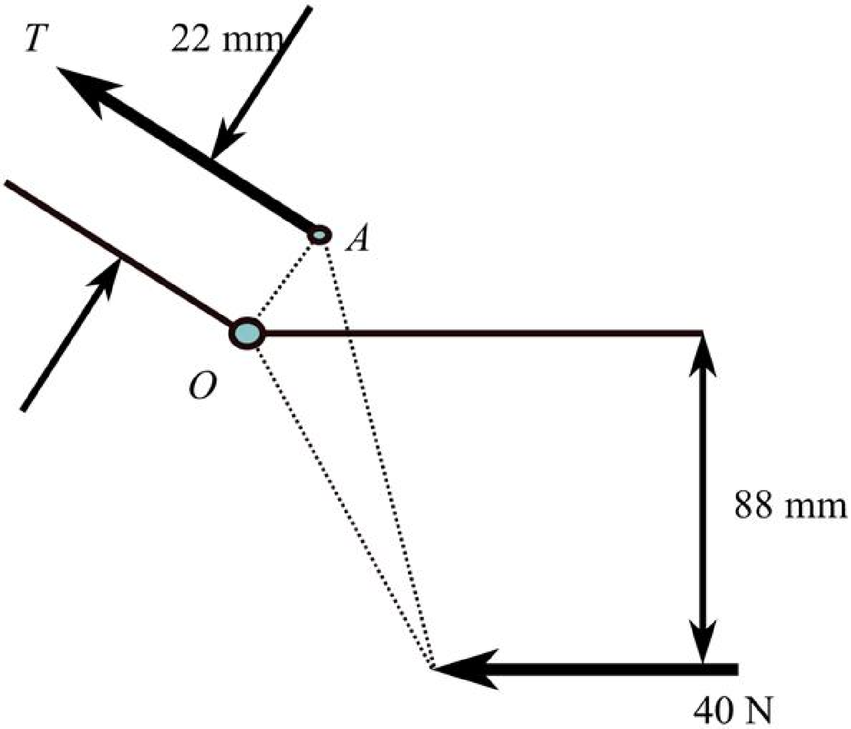
A bicyclist applies a 40-N force to the brake lever of her bicycle as shown. Determine the corresponding tension *T* transmitted to the brake cable. Neglect friction at the pivot *O*.



Step-by-step solution

Step 1 of 2

The first step is to draw a free body diagram. The shape of the bike lever can be simplified since it is a solid, rigid body.



Step 2 of 2

To solve for *T*, simply sum the moments around point *O*.

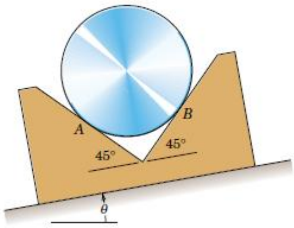
$$\sum M_o = 0$$
$$\sum M_o = (22 \times T) - (88 \times 40)$$
$$(22 \times T) - (88 \times 40) = 0$$
$$T = 160 \text{ N}$$

Therefore the tension in the brake cable is $\boxed{160 \text{ N}}$

Chapter 3, Problem 27P

Problem

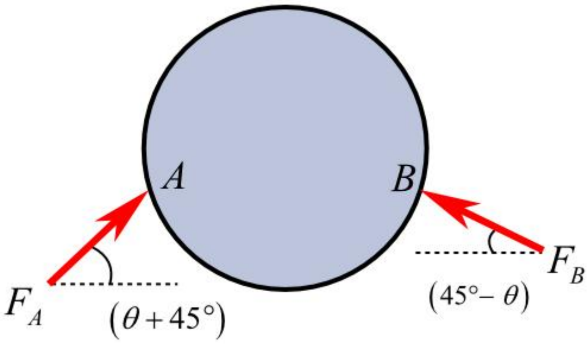
Find the angle of tilt θ with the horizontal so that the contact force at *B* will be one-half that at *A* for the smooth cylinder.



Step-by-step solution

Step 1 of 3

Draw the free body diagram of the cylinder.



Step 2 of 3

Resolve the forces along the *x*-axis.

$$\sum F_x = 0$$
$$F_A \cos(\theta+45°) - F_B \cos(45°-\theta) = 0$$
$$F_A \cos(\theta+45°) = F_B \cos(45°-\theta)$$

Substitute $\frac{F_A}{2}$ for F_B (since the force at B is equal to half the force of A).

$$F_A \cos(\theta+45°) = \frac{F_A}{2}\cos(45°-\theta)$$
$$2\cos(\theta+45°) = \cos(45°-\theta)$$

Substitute u for $(\theta+45°)$.

$$2\cos u = \cos(90°-u)$$
$$2\cos u = \sin u$$
$$2 = \tan u$$
$$u = 63.43°$$

Comments (1)

Anonymous
how cos(90-u) change to sin u?

Step 3 of 3

Calculate the angle θ by using the following relation:

$$\theta = u - 45°$$

Substitute $63.43°$ for u.

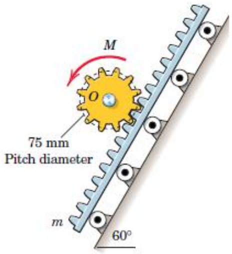
$$\theta = 63.43° - 45°$$
$$= 18.43°$$

Therefore, the angle of tilt with respect to horizontal is $\boxed{18.43°}$.

Chapter 3, Problem 28P

Problem

The rack has a mass m = 75 kg. What moment M must be exerted on the gear wheel by the motor in order to lower the rack at a slow steady speed down the 60° incline? Neglect all friction. The fixed motor which drives the gear wheel via the shaft at O is not shown.

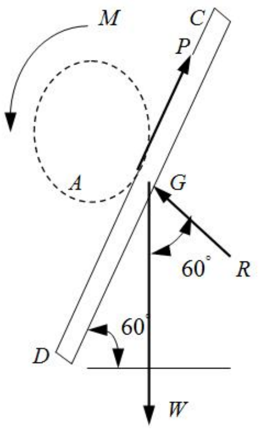


Step-by-step solution

Step 1 of 2

Draw the free body diagram of the rack system.

Step 2 of 2



Determine weight W of the rack by the formula as;

$W = m \times g$

Here, m mass of the body and g is the acceleration due to gravity.

Substitute $75\,\text{kg}$ for m and $9.81\,\text{m/s}^2$ for g.

$$W = 75\,\text{kg} \times 9.81\,\text{m/s}^2$$
$$= 735.75\,\text{N}$$

Apply equilibrium of forces along the length of the rack.

$$\sum F_x = 0$$
$$P - W\sin 60° = 0$$
$$P = W\sin 60°$$

Substitute $735.75\,\text{N}$ for W.

$$P = 735.75\sin 60°$$
$$= 637.18\,\text{N}$$

Determine the moment M exerted on the wheel A.

$$M = P \times d$$

Substitute $637.18\,\text{N}$ for P and $0.075\,\text{m}$ for d.

$$M = 637.18\,\text{N} \times 0.075\,\text{m}$$
$$= 47.78\,\text{N}\cdot\text{m}$$

Therefore, the moment to be exerted on the gear wheel by the motor is $\boxed{47.78\,\text{N}\cdot\text{m}}$ to lower the rack at a slow steady speed.

Comments (2)

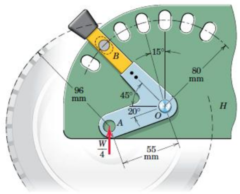
Anonymous
multiply by .0375 instead because thats the radius

Anonymous
incorrect, not taking the moment caused by W into account

Chapter 3, Problem 29P

Problem

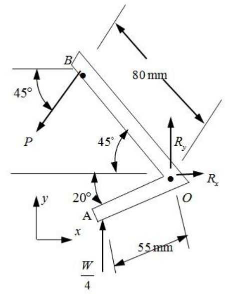
The elements of a wheel-height adjuster for a lawn mower are shown. The wheel (partial outline shown dashed for clarity) bolts through the hole at *A*, which goes through the bracket but not the housing *H*. A pin fixed to the back of the bracket at *B* fits into one of the seven elongated holes of the housing. For the position shown, determine the force at the pin *B* and the magnitude of the reaction at the pivot *O*. The wheel supports a force of magnitude *W*/4, where *W* is the weight of the entire mower.



Step-by-step solution

Step 1 of 6

Draw the free-body diagram of the bracket.



Step 2 of 6

The wheel of the lawn mower exerts a vertically upward force $W/4$ to the bracket AOB at point A. Here, W is the weight of the mower. The housing applies a reaction force P at right angle to the arm OB at point B. Take components of the reaction R at the pivot point O as R_x and R_y in x and y directions respectively.

When a body is under the action of a number of forces in equilibrium, the resultant force and the resultant moment are both zero. Thus the algebraic sum of components of forces along x and y axis as well as the algebraic sum of moments of the forces about any point on the bracket is zero.

Therefore, $\sum F_x = 0, \sum F_y = 0, \text{ and } \sum M = 0$.

Step 3 of 6

Consider the force at B:

Equate the sum of moments of the forces acting on the bracket about point O to zero.

$$\sum M_O = 0$$

$$P \times 80\,\text{mm} - \frac{W}{4} \times 55\,\text{mm} \times \cos 20° = 0$$

Rearrange and simplify to find P.

$$\begin{aligned} P &= \frac{\frac{W}{4} \times 55\,\text{mm} \times \cos 20°}{80\,\text{mm}} \\ &= 0.161509\,W \end{aligned}$$

Therefore, the magnitude of force at the pin B is $\boxed{0.161509\,W}$.

Step 4 of 6

Consider the reactions at O:

Equate the sum of forces along x axis to zero.

$$\sum F_x = 0$$

$$R_x - P\cos 45° = 0$$

Rearrange and simplify to find R_x.

$$R_x = P\cos 45°$$

Substitute $0.16159\,W$ for P and 0.70711 for $\cos 45°$.

$$R_x = 0.161509\,W \times 0.70711 = 0.1142\,W$$

Step 5 of 6

Equate the sum of forces along y axis to zero.

$$\sum F_y = 0$$

$$R_y - P\sin 45° + \frac{W}{4} = 0$$

Rearrange and simplify to find R_y.

$$R_y = P\sin 45° - \frac{W}{4}$$

Substitute $0.16\,W$ for P and 0.70711 for $\sin 45°$.

$$\begin{aligned} R_y &= 0.161509\,W \times 0.70711 - 0.25\,W \\ &= -0.1358\,W \end{aligned}$$

Negative sign indicates that the direction of R_y is opposite to the direction chosen.

Step 6 of 6

Calculate the net magnitude of reaction R at point O using the following relation.

$$R = \sqrt{(R_x)^2 + (R_y)^2}$$

Substitute $0.1142\,W$ for R_x and $0.1358\,W$ for R_y.

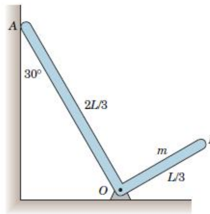
$$\begin{aligned} R &= \sqrt{(0.1142\,W)^2 + (0.1358\,W)^2} \\ &= 0.177435284\,W \\ &= 0.1774\,W \end{aligned}$$

Therefore, magnitude of the reaction at pivot O is $\boxed{0.1774\,W}$.

Chapter 3, Problem 30P

Problem

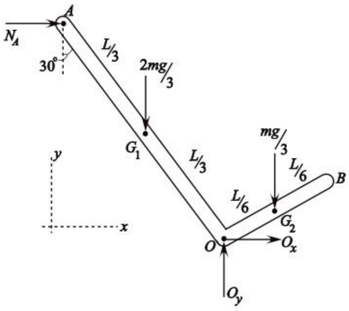
The right-angle uniform slender bar *AOB* has mass *m*. If friction at the pivot *O* is neglected, determine the magnitude of the normal force at *A* and the magnitude of the pin reaction at *O*.



Step-by-step solution

Step 1 of 4

Draw the schematic diagram.



Step 2 of 4

Calculate the magnitude of the normal force at point *A*.

Calculate the moments about point *O*.

$$\sum M_O = 0$$

$$-N_A\left(\frac{2L}{3}\cos 30°\right)+\frac{2mg}{3}\left(\frac{L}{3}\sin 30°\right)-\frac{mg}{3}\left(\frac{L}{6}\cos 30°\right)=0$$

Here, N_A is the normal force at point *A*, *L* is the length of the bar, *m* is the mass of the bar, and *g* is the acceleration due to gravity.

$$-0.577LN_A+0.111mgL-0.048mgL=0$$
$$-0.577LN_A=-0.063mgL$$
$$N_A=0.1091mg$$

Hence, the magnitude of the normal force at point *A* is $\boxed{0.1091mg}$.

Step 3 of 4

Calculate the forces acting on *y*-axis.

$$\sum F_y = 0$$

$$O_y-\frac{2mg}{3}-\frac{mg}{3}=0$$

$$O_y=\frac{3mg}{3}$$
$$=mg$$

Calculate the forces acting on *x*-axis.

$$\sum F_x = 0$$

$$O_x+N_A=0$$

Substitute $0.1091mg$ for N_A.

$$O_x+0.1091mg=0$$
$$O_x=-0.1091mg$$

Step 4 of 4

Calculate the magnitude of the pin reaction at point *O*.

$$O=\sqrt{O_x^2+O_y^2}$$

Substitute mg for O_y, and $-0.1091mg$ for O_x.

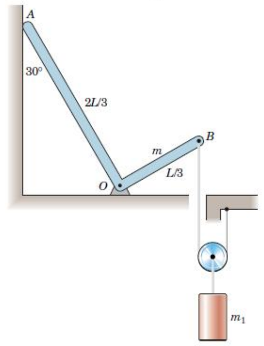
$$O=\sqrt{(-0.1091mg)^2+(mg)^2}$$
$$=\sqrt{0.0119m^2g^2+m^2g^2}$$
$$=1.006mg$$

Hence, the magnitude of the pin reaction at point *O* is $\boxed{1.006mg}$.

Chapter 3, Problem 31P

Problem

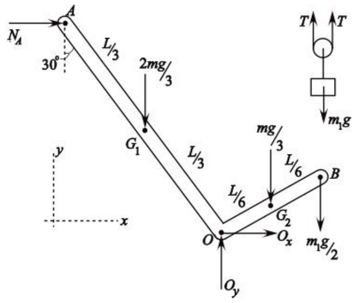
Determine the minimum cylinder mass mx required to cause loss of contact at *A*.



Step-by-step solution

Step 1 of 3

Draw the schematic diagram.



Comments (1)

Anonymous

Why is there two centers of mass? G1 & G2? Are we allowed to treat them as their own rigid bodies?

Step 2 of 3

Consider the pulley.

Calculate the forces acting on *y*-axis.

$$\sum F_y = 0$$

$$2T - m_1 g = 0$$
$$2T = m_1 g$$

Here, *T* is the tension, m_1 is the mass of the cylinder, and *g* is the acceleration due to gravity.

$$T = \frac{m_1 g}{2}$$

Comments (2)

Anonymous

why is Oy disregarded

Anonymous

Because He regarded only the pulley

Step 3 of 3

Calculate the minimum cylinder mass m_1.

Calculate the moments about point *O*.

$$\sum M_O = 0$$

$$\frac{2mg}{3}\left(\frac{L}{3}\sin 30^\circ\right) - \frac{mg}{3}\left(\frac{L}{6}\cos 30^\circ\right) - T\left(\frac{L}{3}\cos 30^\circ\right) = 0$$

Here, *L* is the length of the bar, and *m* is the mass of the bar.

Substitute $\frac{m_1 g}{2}$ for *T*.

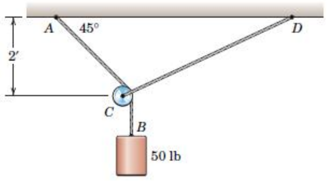
$$\frac{2mg}{3}\left(\frac{L}{3}\sin 30^\circ\right) - \frac{mg}{3}\left(\frac{L}{6}\cos 30^\circ\right) - \frac{m_1 g}{2}\left(\frac{L}{3}\cos 30^\circ\right) = 0$$
$$0.111mgL - 0.048mgL - 0.144m_1 gL = 0$$
$$0.063mgL = 0.144m_1 gL$$
$$0.063m = 0.144m_1$$

$$m_1 = 0.436m$$

Hence, the minimum cylinder mass m_1 is $\boxed{0.436m}$.

Problem

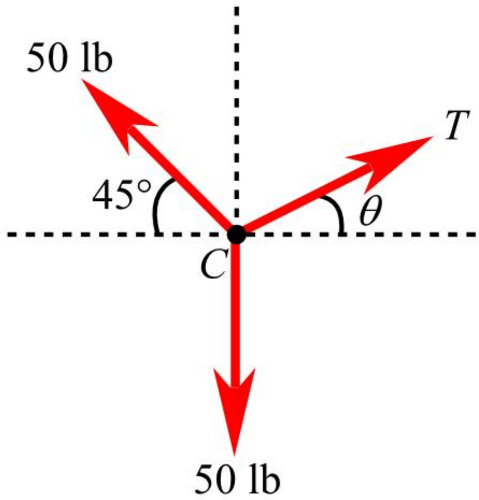
Cable *AB* passes over the small ideal pulley *C* without a change in its tension. What length of cable *CD* is required for static equilibrium in the position shown? What is the tension *T* in cable *CD*?



Step-by-step solution

Step 1 of 3

Draw the free body diagram at joint C.



Step 2 of 3

Resolve the forces along *x*-direction.

$$\sum F_x = 0$$
$$T\cos\theta - 50\cos 45° = 0 \quad \cdots\cdots (1)$$
$$T\cos\theta = 35.4$$

Resolve the forces along *y*-direction.

$$\sum F_y = 0$$
$$T\sin\theta + 50\sin 45° - 50 = 0 \quad \cdots\cdots (2)$$
$$T\sin\theta = 14.6$$

Divide the equation (2) by (1).

$$\frac{T\sin\theta}{T\cos\theta} = \left(\frac{14.6}{35.4}\right)$$
$$\tan\theta = \left(\frac{14.6}{35.4}\right)$$
$$\theta = 22.4°$$

Step 3 of 3

Substitute $22.4°$ for θ in equation (1).

$$T\cos\theta = 35.4$$
$$T\cos 22.4° = 35.4$$
$$T = 38.3\,\text{lb}$$

Therefore, the tension in the cable *CD* is $\boxed{38.3\,\text{lb}}$.

Calculate the length of the cable *CD* using the geometry.

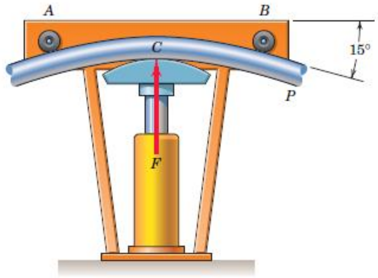
$$\sin\theta = \frac{2}{CD}$$
$$\sin 22.4 = \frac{2}{CD}$$
$$CD = 5.25\,\text{ft}$$

Therefore, the length of the cable *CD* is $\boxed{5.25\,\text{ft}}$.

Chapter 3, Problem 33P

Problem

A pipe P is being bent by the pipe bender as shown. If the hydraulic cylinder applies a force of magnitude F = 24 kN to the pipe at C, determine the magnitude of the roller reactions at A and B.



Step-by-step solution

Step 1 of 1

Consider the forces acting on the pipe in vertical direction.

$$\sum F = 0$$
$$F - N_A \cos 15° - N_B \cos 15° = 0$$

Here, F is the force exerted by the hydraulic cylinder on pipe, N_A is roller reaction on the pipe at A, N_B is roller reaction on the pipe at B.

Substitute 24 kN for F, N_B for N_A.

$$F - N_A \cos 15° - N_B \cos 15° = 0$$
$$24 - 2N_A \cos 15° = 0$$
$$N_A = 12.42\text{ kN}$$

Therefore, roller reaction on the pipe at A, N_A, is $\boxed{12.42\text{ kN}}$

Since roller reaction on the pipe at A is equal to roller reaction on the pipe at B.

Hence, roller reaction on the pipe at B, N_B, is $\boxed{12.42\text{ kN}}$

Comments (7)

Anonymous
incorrect.

Anonymous
It is correct^

Anonymous
Can somebody explain why it is cos for the vertical direction and not sin? With a diagram showing the angles please.

Anonymous
i would like to know as well :)

Anonymous
This example is very intuitive if a free-body diagram is drawn. Always draw one if you feel insecure with angles and/or perpendicular lengths. Also always put out a coordinate system so it's easier to explain if need be. (continue in next comment)

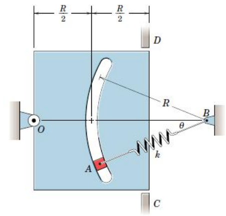
Anonymous
F is applied in vertical direction. Reaction forces are normal to the contact point between the pipe and rollers making them both horizontal and vertical. (continue in next comment)

Anonymous
To see that the shown angle is the same angle N makes with the vertical axis it's easiest to draw the free-body diagram and sketch a horizontal line followed by a tangent line cutting the pipe/roller contact point. By making perpendicular lines with these lines you'll visually see were the angle is 75° and were it's 15°. Then you need to follow the rules of sine and cosine to decide what angle that goes with what.

Chapter 3, Problem 34P

Problem

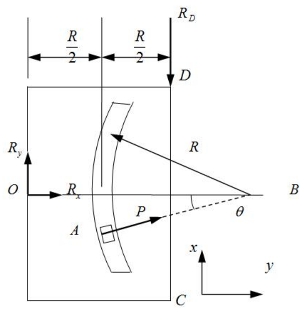
The small slider *A* is moved along the circular slot by a mechanism attached to the back side of the rectangular plate. For the slider position *θ* = 20° shown, determine the normal forces exerted at the small stops *C* and *D*. The unstretched length of the spring of constant *k* = 1.6 kN/m is *R*/3. The value of *R* is 25 mm, and the plate lies in a horizontal plane. Neglect all friction.



Step-by-step solution

Step 1 of 6

Draw the free-body diagram of the plate.



Step 2 of 6

The slider A moves along the circular slot of the rectangular plate. The spring force P is on the side of stop C in the given position. So the rectangular plate will rotate about pivot O towards stop D. The plate will touch the stop D and loose contact with the stop C. Hence there will be a normal reaction R_D at D and no reaction force at C. Consider the components of reaction at O as R_x and R_y in x and y directions respectively. Un-stretched length of the spring is $R/3$ and the stretched length is R.

When a body, under the action of a number of forces is in equilibrium, the resultant force and resultant moment are both zero. Thus algebraic sum of the components of the forces along x and y axis, as well as algebraic sum of moments of the forces about any point are zero. Mathematically, $\sum F_x = 0, \sum F_y = 0, \text{ and } \sum M = 0$.

Step 3 of 6

Consider the elongation, δ of the spring.

$$\begin{aligned}\delta &= R - \frac{R}{3} \\ &= \frac{2R}{3}\end{aligned}$$

Calculate the spring force using the following formula.

$$P = k \times \delta = k \times \frac{2R}{3} = \frac{2kR}{3}$$

Here, k is the spring constant.

Step 4 of 6

Consider the normal force R_D at D:

Equate the sum of moments of the forces acting on the plate about point O to zero.

$$\sum M_O = 0$$

$$R_D \times \left(\frac{R}{2} + \frac{R}{2}\right) - P\cos\theta \times R\sin\theta - P\sin\theta \times \left\{\frac{R}{2} + (R - R\cos\theta)\right\} = 0$$

Rearrange and simplify to find R_D. Thus

$$\begin{aligned}R_D &= \frac{P\cos\theta \times R\sin\theta + P\sin\theta \times R \times \left(\frac{1}{2} + 1 - \cos\theta\right)}{\left(\frac{R}{2} + \frac{R}{2}\right)} \\ &= \frac{P \times R \times \left(\sin\theta\cos\theta + \frac{3\sin\theta}{2} - \sin\theta\cos\theta\right)}{R} \\ &= P \times \frac{3\sin\theta}{2}\end{aligned}$$

Step 5 of 6

Replace $\frac{2kR}{3}$ for P.

$$\begin{aligned}R_D &= \frac{2kR}{3} \times \frac{3\sin\theta}{2} \\ &= kR\sin\theta\end{aligned}$$

Substitute $1.6 \times 10^3\ \mathrm{N/m}$ for k, $25 \times 10^{-3}\ \mathrm{m}$ for R and $20°$ for θ.

$$\begin{aligned}R_D &= \left(1.6 \times 10^3\ \mathrm{N/m}\right) \times \left(25 \times 10^{-3}\ \mathrm{m}\right) \times \sin 20^\circ \\ &= (1.6 \times 25\ \mathrm{N}) \times \sin 20^\circ \\ &= 13.681\ \mathrm{N}\end{aligned}$$

Therefore, the normal force at stop D is $\boxed{13.681\ \mathrm{N}}$.

Step 6 of 6

Consider the normal force at C:

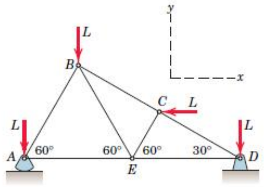
The plate will touch the stop D and loose contact with the stop *C*.

Therefore, the normal force at stop C is $\boxed{0}$.

Chapter 3, Problem 35P

Problem

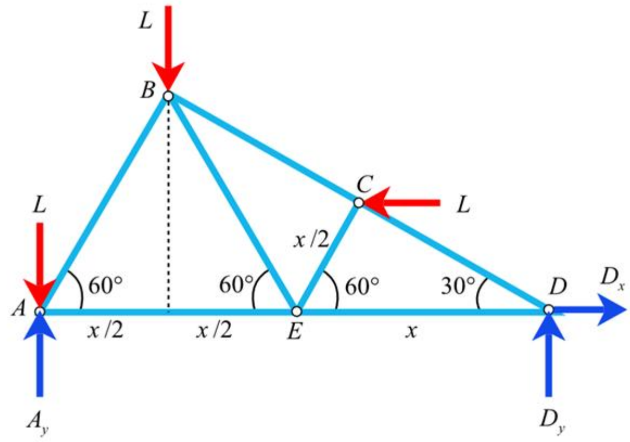
The asymmetric simple truss is loaded as shown. Determine the reactions at *A* and *D*. Neglect the weight of the structure compared with the applied loads. Is knowledge of the size of the structure necessary?



Step-by-step solution

Step 1 of 4

Draw the free body diagram of the truss.



Step 2 of 4

Take moment about *A*.

$$\sum M_A = 0$$
$$D_y(2x) - L(2x) - L\left(\frac{x}{2}\right) + L\left(\frac{x\sin 60^\circ}{2}\right) = 0$$
$$2D_y - 2L - \left(\frac{L}{2}\right) + \left(\frac{L\sin 60^\circ}{2}\right) = 0$$
$$2D_y - 2.066L = 0$$
$$D_y = 1.033L$$

Here, *x* is length of the member *AE*.

Therefore, the vertical reaction at *D* is $\boxed{1.033L}$.

Step 3 of 4

Resolve the forces along *x*-axis.

$$\sum F_x = 0$$
$$D_x - L = 0$$
$$D_x = L$$

Therefore, the horizontal reaction at *D* is $\boxed{L}$.

Step 4 of 4

Resolve the forces along *y*-axis.

$$\sum F_y = 0$$
$$D_y + A_y - L - L - L = 0$$

Substitute $1.033L$ for D_y.

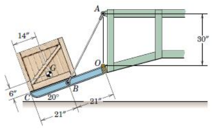
$$1.033L + A_y - L - L - L = 0$$
$$A_y = 1.967L$$

Therefore, the vertical reaction at *A* is $\boxed{1.967L}$.

Chapter 3, Problem 36P

Problem

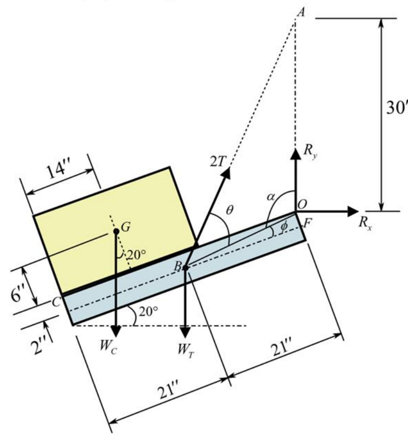
The tailgate *OBC* is attached to the rear of a trailer via hinges at *O* and two restraining cables *AB*. The 120-lb tailgate is 4 in. thick with center of gravity at *B*, which is at midthickness. The crate is centered between the two cables and weighs 200 lb with center of gravity at *G*. Determine the tension *T* in each cable.



Step-by-step solution

Step 1 of 5

Draw the free-body diagram of the tailgate.



Step 2 of 5

Calculate the length of *BF* by considering the tringle *BOF*.

$$OB = \sqrt{BF^2 + OF^2}$$

Substitute 21 in. for *BF* and 2 in. for *OF*.

$$\begin{aligned} OB &= \sqrt{(21\text{ in.})^2 + (2\text{ in.})^2} \\ &= 21.095\text{ in.} \end{aligned}$$

Calculate the angle ϕ by using the trigonometry relation.

$$\tan\phi = \frac{OF}{BF}$$

Substitute 21 in. for *BF* and 2 in. for *OF*.

$$\phi = \tan^{-1}\left(\frac{OF}{BF}\right)$$

$$\begin{aligned} \phi &= \tan^{-1}\left(\frac{2\text{ in.}}{21\text{ in.}}\right) \\ &= 5.44^\circ \end{aligned}$$

Step 3 of 5

Calculate the angle α by using the geometry of the figure.

$$\alpha = 90^\circ + 20^\circ + \phi$$

Substitute 5.44° for ϕ.

$$\begin{aligned} \alpha &= 90^\circ + 20^\circ + 5.44^\circ \\ &= 115.44^\circ \end{aligned}$$

Calculate the length of *AB* by using cosine rule.

$$AB = \sqrt{AO^2 + BO^2 - 2\times AO \times BO \times \cos\alpha}$$

Substitute 30 in. for AO, 21.095 in. for BO, and 115.44° for α.

$$\begin{aligned} AB &= \sqrt{(30\text{ in.})^2 + (21.095\text{ in.})^2 - 2\times(30\text{ in.})\times(21.095\text{ in.})\times\cos 115.44^\circ} \\ &= 43.459\text{ in.} \end{aligned}$$

Step 4 of 5

Calculate the angle θ by using sine rule.

$$\frac{\sin\theta}{AO} = \frac{\sin\alpha}{AB}$$

$$\sin\theta = \frac{AO}{AB}\sin\alpha$$

Substitute 30 in. for AO, 43.459 in. for AB, and 115.44° for α.

$$\sin\theta = \frac{30\text{ in.}\times\sin 115.44^\circ}{43.459\text{ in.}}$$

$$\sin\theta = 0.623$$

$$\theta = \sin^{-1}(0.624)$$

$$\theta = 38.536^\circ$$

Step 5 of 5

The tension in cable *BA* is 2*T* as there are two cables from *B* to *A*.

Calculate the tension in the cable *AB* by taking moments about point *O*.

$$\sum M_O = 0$$

$$\begin{bmatrix} 2T\sin\theta\times 21.095\text{ in.} - W_C\cos 20^\circ\times(21+21-14)\text{in.} - W_C\sin 20^\circ\times 6\text{ in.} \\ -W_T\cos 20^\circ\times 21\text{ in} + \mathrm{W}_T\sin 20^\circ\times 2\text{ in.} = 0 \end{bmatrix}$$

$$T = \frac{W_C\times(28\cos 20^\circ + 6\sin 20^\circ) + W_T\times(21\cos 20^\circ - 2\sin 20^\circ)}{2\times 21.095\sin\theta}$$

Here, *T* is the tension in cable *AB*, W_C is the weight of the crater, and W_T is the weight of the tailgate.

Substitute 200 lbf for W_C, 120 lbf for W_T, and 38.536° for θ.

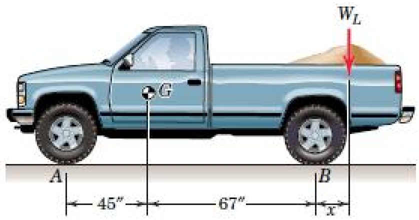
$$\begin{aligned} T &= \frac{200\text{ lbf}\times(28\cos 20^\circ + 6\sin 20^\circ) + 120\text{ lbf}\times(21\cos 20^\circ - 2\sin 20^\circ)}{2\times 21.095\times\sin 38.539^\circ} \\ &= \frac{200\times(26.311 + 2.052) + 120\times(19.733 - 0.684)}{26.286} \\ &= 303\text{ lb} \end{aligned}$$

Therefore, the tension in each cable is $\boxed{303\text{ lb}}$.

Chapter 3, Problem 37P

Problem

The indicated location of the center of gravity of the 3600-lb pickup truck is for the unladen condition. If a load whose center of gravity is x = 16 in. behind the rear axle is added to the truck, determine the load weight *WL* for which the normal forces under the front and rear wheels are equal.



Step-by-step solution

Step 1 of 3

Take moment about *A*.

$$\sum M_A = 0$$
$$R_B(112) - 3600(45) - W_L(128) = 0$$
$$112R_B - 162000 - 128W_L = 0 \qquad [\because R_A = R_B = R] \quad \ldots\ldots (1)$$
$$112R - 162000 - 128W_L = 0$$

Resolve the forces along *y*-axis.

$$\sum F_y = 0$$
$$R_A + R_B - 3600 - W_L = 0$$
$$2R - 3600 - W_L = 0 \qquad [\because R_A = R_B = R] \quad \ldots\ldots (2)$$
$$W_L = 2R - 3600$$

Step 2 of 3

Substitute $(2R - 3600)$ for W_L in equation(1).

$$112R - 162000 - 128W_L = 0$$
$$112R - 162000 - 128(2R - 3600) = 0$$
$$460800 - 144R - 162000 = 0$$
$$144R = 298800$$
$$R = 2075\text{ lb}$$

Therefore, the reaction at front wheels and rear wheels is $\boxed{2075\text{ lb}}$.

Step 3 of 3

Substitute 2075 lb for R in equation (2).

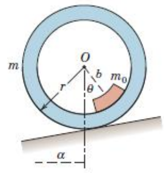
$$W_L = 2R - 3600$$
$$= 2(2075) - 3600$$
$$= 550\text{ lb}$$

Therefore, the load weight is $\boxed{550\text{ lb}}$.

Chapter 3, Problem 38P

Problem

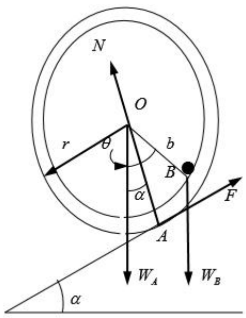
A uniform ring of mass *m* and radius *r* carries an eccentric mass m0 at a radius *b* and is in an equilibrium position on the incline, which makes an angle *a* with the horizontal. If the contacting surfaces are rough enough to prevent slipping, write the expression for the angle *θ* which defines the equilibrium position.



Step-by-step solution

Step 1 of 3

Draw the free body diagram of the composite ring.



Here, $OA = r$, $OB = b$. Angle between the normal reaction N and the weight W_A is α. Angle between OB and the weight W_A is θ. Weights W_A and W_B are given by $W_A = mg$ and $W_B = m_0 g$.

Step 2 of 3

The weight W_A of the ring acts vertically downwards through its centre O. The ring slips on an inclined plane of angle α with the horizontal. A normal reaction force N is applied to the ring at the contact point A along AO. Take the frictional force at A as F along the inclined plane in upward direction. The weight W_B of the eccentric mass B acts vertically downward through B. OB makes an angle θ with the vertical.

When a body, under the action of a number of forces is in equilibrium, the resultant force and the resultant couple are both zero. Thus algebraic sum of components of the forces along x and y axes, as well as algebraic sum of moments of the forces about any point are zero. Mathematically, $\sum F_x = 0$, $\sum F_y = 0$, and $\sum M = 0$.

Step 3 of 3

Determination of angle θ:

Consider the sum of moments of the forces about point A to zero.

$$\sum M_A = 0.$$

$$W_A \times r\sin\alpha - W_B \times (b\sin\theta - r\sin\alpha) = 0$$

$$mg \times r\sin\alpha - m_0 g \times (b\sin\theta - r\sin\alpha) = 0$$

$$m_0 b\sin\theta = mr\sin\alpha + m_0 r\sin\alpha$$

$$\sin\theta = \frac{(m+m_0)r\sin\alpha}{m_0 b}$$

$$\theta = \sin^{-1}\left[\frac{(m+m_0)r\sin\alpha}{m_0 b}\right]$$

$$= \sin^{-1}\left[\frac{r}{b}\left(1+\frac{m}{m_0}\right)\sin\alpha\right]$$

Therefore, the angle θ for equilibrium position of the composite ring with eccentric mass is $\boxed{\sin^{-1}\left[\frac{r}{b}\left(1+\frac{m}{m_0}\right)\sin\alpha\right]}$.

Comments (1)

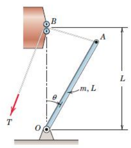
Anonymous

How do you get the moment for WB?

Chapter 3, Problem 39P

Problem

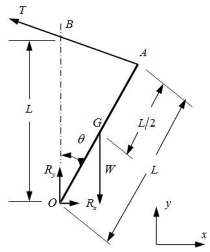
Determine the force T required to hold the uniform bar of mass m and length L in an arbitrary angular position θ. Plot your result over the range $0 \le \theta \le 90°$, and state the value of T for $\theta = 40°$.



Step-by-step solution

Step 1 of 6

Draw the free-body diagram of the bar.



Step 2 of 6

Neglect friction in the system. The force that acts on the bar OA at A along AB is T. The weight W of the bar acts vertically downward through its center of gravity, G. Resolve the components of the reaction at the pivot O as R_x and R_y along x and y axes respectively.

Here, from the diagram, $OA = OB$ and the sum of the angles of the triangle OAB is π.

Consider the triangles OAB and OBA.

$$\angle OAB = \angle OBA = \frac{\pi - \theta}{2} = \left(\frac{\pi}{2} - \frac{\theta}{2}\right)$$

Force T has two components along OA and perpendicular to OA. They are $T\cos\left(\frac{\pi}{2} - \frac{\theta}{2}\right)$ and $T\sin\left(\frac{\pi}{2} - \frac{\theta}{2}\right)$ respectively.

Step 3 of 6

When a body under the action of several forces is in equilibrium, the algebraic sum of components of the forces along x and y axes as well as algebraic sum of moments of the forces about any point are all zero. Mathematically, $\sum F_x = 0, \sum F_y = 0,$ and $\sum M = 0$

Determine the tension T in terms of θ:

Equate the sum of moments of the forces about point O to zero.

$$\sum M_O = 0$$

$$T\sin\left(\frac{\pi}{2} - \frac{\theta}{2}\right) \times L - W \times \frac{L}{2}\sin\theta = 0$$

$$T = \frac{W \times \frac{L}{2} \times \sin\theta}{L \times \sin\left(\frac{\pi}{2} - \frac{\theta}{2}\right)}$$

$$= \frac{W \times L \times \sin\frac{\theta}{2} \times \cos\frac{\theta}{2}}{L \times \cos\frac{\theta}{2}}$$

$$= W \times \sin\frac{\theta}{2}$$

Substitute mg for W.

$$T = mg\sin\frac{\theta}{2}$$

Therefore, the force T required to hold the uniform bar of mass m in an arbitrary angular position θ is $\boxed{mg\sin\frac{\theta}{2}}$.

Step 4 of 6

Calculate the value of T for $\theta = 40°$:

Write the expression for T in terms of θ.

$$T = mg\sin\frac{\theta}{2}$$

Substitute $40°$ for θ.

$$T = mg\sin\left(\frac{40°}{2}\right)$$
$$= mg\sin 20°$$
$$= 0.342\,mg$$

Therefore, the value of T for $\theta = 40°$ is $\boxed{0.342\,mg}$.

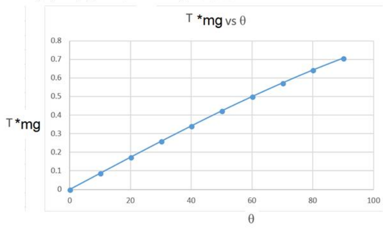
Step 5 of 6

Consider the plot of T against θ for $0 \le \theta \le 90°$:

θ(deg)	T(*mg)=sin(θ/2)
0	0
10	0.087
20	0.1736
30	0.2588
40	0.342
50	0.423
60	0.5
70	0.5735
80	0.643
90	0.707

Step 6 of 6

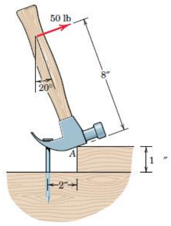
Plot the graph of T against θ over the range $0 \le \theta \le 90°$.



Chapter 3, Problem 40P

Problem

A block placed under the head of the claw hammer as shown greatly facilitates the extraction of the nail. If a 50-lb pull on the handle is required to pull the nail, calculate the tension T in the nail and the magnitude A of the force exerted by the hammer head on the block. The contacting surfaces at A are sufficiently rough to prevent slipping.

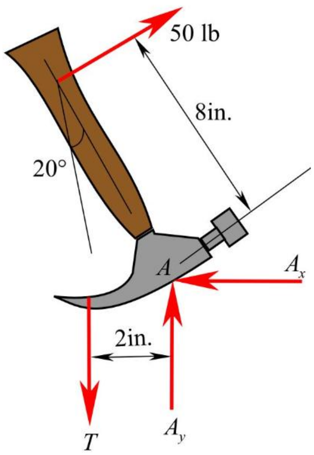


Step-by-step solution

Step 1 of 5

Draw the free body diagram of the claw hammer.

Step 2 of 5



Comments (3)

Anonymous
Can you explain why Ay is upwards and Ax is to the leff?

Anonymous
left*

Anonymous
they cray

Step 3 of 5

Calculate the tension in the nail.

Apply equilibrium condition.

Take moment about point A.

$$\sum M_A = 0$$
$$50(8) - T(2) = 0$$
$$400 - 2T = 0$$
$$T = 200 \text{ lb}$$

Therefore, the tension in the nail is $\boxed{200 \text{ lb}}$.

Step 4 of 5

Resolve the forces along horizontal direction.

$$\sum F_x = 0$$
$$50\cos 20° - A_x = 0$$
$$A_x = 50\cos 20°$$
$$A_x = 46.98 \text{ lb}$$

Resolve the forces along vertical direction.

$$\sum F_y = 0$$
$$50\sin 20° + A_y - T = 0$$

Substitute 200 lb for T.

$$50\sin 20° + A_y - 200 = 0$$
$$A_y = 200 - 50\sin 20°$$
$$A_y = 182.9 \text{ lb}$$

Step 5 of 5

Calculate the magnitude at A.

$$A = \sqrt{A_x^2 + A_y^2}$$

Substitute 46.98 lb for A_x and 182.9 lb for A_y.

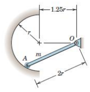
$$A = \sqrt{46.98^2 + 182.9^2}$$
$$A = 188.8 \text{ lb}$$

Therefore, the magnitude at A is $\boxed{188.8 \text{ lb}}$.

Chapter 3, Problem 41P

Problem

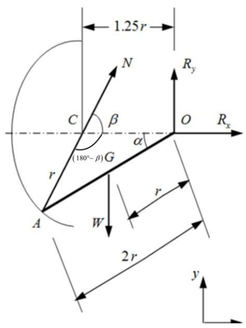
The uniform slender bar of length 2*r* and mass *m* rests against the circular surface as shown. Determine the normal force at the small roller *A* and the magnitude of the ideal pivot reaction at *O*.



Step-by-step solution

Step 1 of 8

Draw the free-body diagram of the slender bar.



Step 2 of 8

The bar OA of length $2r$ is hinged at O and rests on a circular surface through a roller at A. Note that the normal reaction N on the bar at A will pass through the center C of the circular surface. Consider the angle made by the force N with x axis as β. The weight $W(=mg)$ of the bar acts vertically downwards through its mid-point G. Resolve the components of the reaction R on the bar at O as R_x and R_y in x and y directions respectively. Consider the angle made by OA with the horizontal CO as α.

Step 3 of 8

Determine $\angle AOC(=\alpha)$ by applying cosine rule for triangle *AOC*.

$$\cos\alpha=\frac{OC^2+OA^2-AC^2}{2\times OC\times OA}$$

Substitute $1.25r$ for OC, $2r$ for OA and r for AC.

$$\begin{aligned}\cos\alpha&=\frac{(1.25r)^2+(2r)^2-(r)^2}{2\times(1.25r)\times(2r)}\\&=\frac{(1.5625+4-1)\times r^2}{5\times r^2}\\&=0.9125\\\alpha&=24.1^\circ\end{aligned}$$

Step 4 of 8

Determine the angle β:

From the diagram, $\angle ACO=(180^\circ-\beta)$

Determine the angle β by applying cosine rule for triangle *ACO*.

$$\cos(180^\circ-\beta)=\frac{OC^2+AC^2-AO^2}{2\times OC\times AC}$$

Substitute $1.25r$ for OC, $2r$ for OA and r for AC.

$$\cos(180^\circ-\beta)=\frac{(1.25r)^2+(r)^2-(2r)^2}{2\times(1.25r)\times(r)}$$

$$\cos(180^\circ-\beta)=\frac{(1.5625+1-4)\times r^2}{2.5\times r^2}$$

$$\cos(180^\circ-\beta)=-0.575$$

$$\cos\beta=0.575$$

$$\beta=54.9^\circ$$

Step 5 of 8

Determine the normal reaction at A by equating sum of moments of the forces acting on the bar about point O to zero.

$$\sum M_O=0$$

$$N\cos\beta\times(2r\sin\alpha)-N\sin\beta\times(2r\cos\alpha)+mg\times(r\cos\alpha)=0$$

$$\begin{aligned}N&=\frac{r\times mg\cos\alpha}{r\times(2\sin\beta\cos\alpha-2\cos\beta\sin\alpha)}\\&=\frac{mg\cos\alpha}{2\sin(\beta-\alpha)}\end{aligned}$$

Substitute 24.1° for α, 54.9° for β.

$$\begin{aligned}N&=\frac{mg\cos 24.1^\circ}{2\sin(54.9^\circ-24.1^\circ)}\\&=\frac{mg\times0.9125}{2\times0.51204}\\&=0.89104\,mg\\&=0.891mg\end{aligned}$$

Therefore, the normal force at the smaller roller is $\boxed{0.891mg}$.

Comments (2)

Anonymous
please can you explain why the perpendicular distance to N is 2rsin alpha

Anonymous
oh never mind

Step 6 of 8

Determine the pivot reaction at O by equating the algebraic sum of forces on the bar along x axis to zero.

$$\sum F_x=0$$

$$R_x+N\cos\beta=0$$

$$R_x=-N\cos\beta$$

Negative sign indicates that the direction of R_x is opposite to the direction chosen.

Substitute $0.891mg$ for N and 54.9° for β.

$$\begin{aligned}R_x&=-0.891mg\times\cos 54.9^\circ\\&=-0.891mg\times0.575\\&=-0.512329\,mg\end{aligned}$$

Step 7 of 8

Equate the algebraic sum of forces on the bar along y axis to zero.

$$\sum F_y=0$$

$$R_y+N\sin\beta-mg=0$$

$$R_y=mg-N\sin\beta$$

Substitute $0.89mg$ for N and 54.9° for β.

$$\begin{aligned}R_y&=mg-0.891mg\times\sin 54.9^\circ\\&=mg-0.728971mg\\&=0.271029\,mg\end{aligned}$$

Step 8 of 8

Determine magnitude of reaction R at O by the following formula.

$$R=\sqrt{R_x^{\,2}+R_y^{\,2}}$$

Substitute $0.512329mg$ for R_x and $0.271029mg$ for R_y to find R.

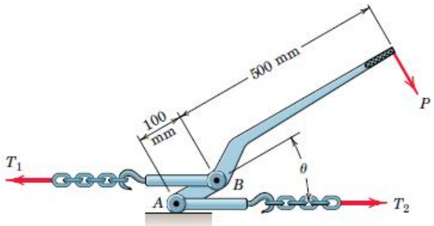
$$\begin{aligned}R&=\sqrt{(0.512329mg)^2+(0.271029mg)^2}\\&=\sqrt{0.26248+0.07345}\,mg\\&=0.579594mg\\&=0.58mg\end{aligned}$$

Therefore, the magnitude of ideal pivot reaction at O is $\boxed{0.58mg}$.

Chapter 3, Problem 42P

Problem

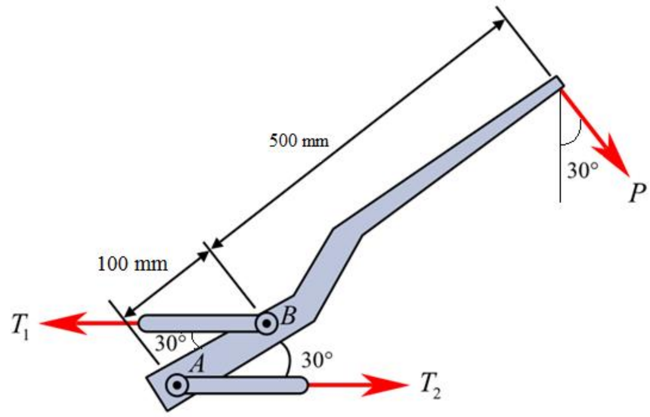
The chain binder is used to secure loads of logs, lumber, pipe, and the like. If the tension *T*1 is 2 kN when *θ* = 30°, determine the force *P* required on the lever and the corresponding tension *T*2 for this position. Assume that the surface under *A* is perfectly smooth.



Step-by-step solution

Step 1 of 3

Draw the free body diagram of the chain binder.



Step 2 of 3

Apply the moment equilibrium condition about point *A*.

$$\sum M_A = 0$$
$$P(500+100) - T_1 \sin 30°(100) = 0$$
$$600P - 50T_1 = 0$$

Here, the force required on the lever is *P* and the tension in the chain connected to the link at point *B* is T_1.

Substitute 2kN for T_1.

$$600P - 50(2) = 0$$
$$600P - 100 = 0$$
$$P = 0.1667\,\text{kN}$$

Therefore, the force required on the lever is $\boxed{0.1667\,\text{kN}}$.

Step 3 of 3

Apply the force equilibrium equation along *x*-direction.

$$\sum F_x = 0$$
$$T_2 + P\sin 30° - T_1 = 0$$

Here, the tension in the chain connected to the link at point *A* is T_2.

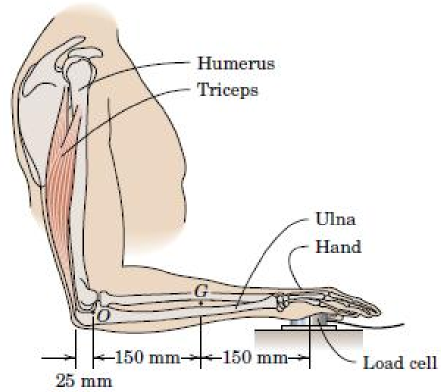
Substitute $0.1667\,\text{kN}$ for *P* and 2kN for T_1.

$$T_2 + (0.1667)\sin 30° - (2) = 0$$
$$T_2 = 1.9166\,\text{kN}$$

Therefore, the tension T_2 is $\boxed{1.9166\,\text{kN}}$.

Problem

In a procedure to evaluate the strength of the triceps muscle, a person pushes down on a load cell with the palm of his hand as indicated in the figure. If the load-cell reading is 160 N, determine the vertical tensile force F generated by the triceps muscle. The mass of the lower arm is 1.5 kg with mass center at G. State any assumptions.

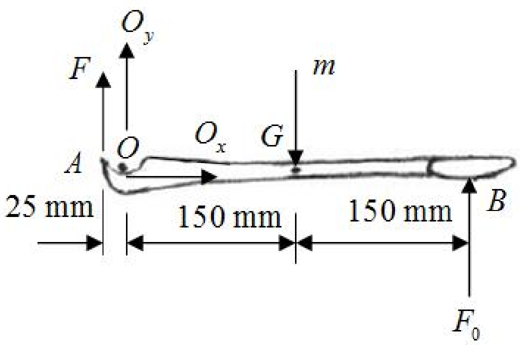


Step-by-step solution

Step 1 of 1

5150-3-39P AID: 2286 | 30/07/2015

Sketch the arm and indicate the forces on it.



F F_0 O A B O_y O_x G m 150 mm 25 mm

Consider the moments on the arm about O.

$$\sum M_o = 0$$
$$-F(L_{OA}) - m(L_{OG}) + F_0(L_{OB}) = 0$$

Here, F is the tensile force generated by the triceps muscles, L_{OA} is the length from O to A, m is the mass of the lower arm, L_{OG} is the distance from O to G, F_0 is the reaction force on the palm, L_{OB} is the distance from O to B.

Substitute 0.025 m for L_{OA}, 1.5 kg for m, 0.15 m for L_{OG}, 16.31 kg for F_0, 0.3 m for L_{OB}.

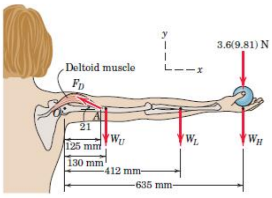
$$-F\times(0.025) - 1.5\times(0.15) + 16.31\times(0.3) = 0$$
$$F = 186.72\text{ kg}$$
$$= 1832\text{ N}$$

Therefore, tensile force generated by the triceps muscles, F, is $\boxed{1832\text{ N}}$

Chapter 3, Problem 44P

Problem

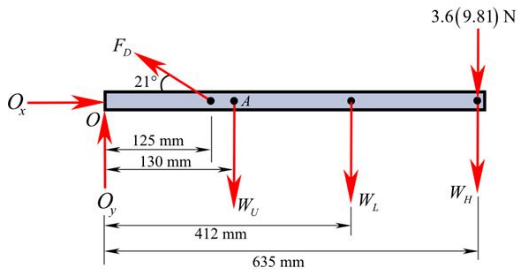
A woman is holding a 3.6-kg sphere in her hand with the entire arm held horizontally as shown in the figure. A tensile force in the deltoid muscle prevents the arm from rotating about the shoulder joint *O*; this force acts at the 21° angle shown. Determine the force exerted by the deltoid muscle on the upper arm at *A* and the *x*- and y-components of the force reaction at the shoulder joint *O*. The mass of the upper arm is mU = 1.9 kg, the mass of the lower arm is mL = 1.1 kg, and the mass of the hand is mH = 0.4 kg; all the corresponding weights act at the locations shown in the figure.



Step-by-step solution

Step 1 of 3

Draw the free body diagram of the hand.



Step 2 of 3

Apply equilibrium condition.

Take moment about *O*.

$$\sum M_A = 0$$
$$F\sin 21°(125)-(1.9\times1.98)(130)-(1.1\times9.81)(412)-\left[(3.6+0.4)\times9.81\right](635)=0$$
$$125F\sin 21°-31786.362=0$$
$$F=710\,\text{N}$$

Therefore, the force exerted by the deltoid muscle $\boxed{710\,\text{N}}$.

Comments (2)

Anonymous
what is the 1.98 for? Shouldn't it be gravity (9.81) like the rest?

Anonymous
i dont understand why Fsin is used twice?

Step 3 of 3

Resolve the forces along *x*-direction.

$$\sum F_x = 0$$
$$O_x - F\cos 21° = 0$$

Substitute $710\,\text{N}$ for F.

$$O_x - 710\cos 21° = 0$$
$$O_x = 662.8\,\text{N}$$

Therefore, the reaction at *O* in x-direction is $\boxed{662.8\,\text{N}}$.

Resolve the forces along *y*-direction.

$$\sum F_y = 0$$
$$O_y + F\sin 21° - (1.9\times9.81) - (1.1\times9.81) - (3.6\times9.81) - (0.4\times9.81) = 0$$

Substitute $710\,\text{N}$ for F.

$$O_y + 710\sin 21° - (1.9\times9.81) - (1.1\times9.81) - (3.6\times9.81) - (0.4\times9.81) = 0$$
$$O_y = -185.7\,\text{N}$$
$$= 185.7\,\text{N}(\uparrow)$$

Therefore, the reaction at *O* in y-direction is $\boxed{185.7\,\text{N}(\uparrow)}$.

Comments (2)

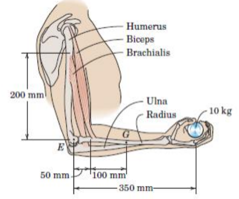
Anonymous
If Oy equals a negative and the FBD has it drawn pointing up with the y-axis, shouldn't the direction arrow in the answer point down?

Anonymous
Wouldn't the arrow in the answer only point up if you left in the negative in the answer? Since its switched to positive in the end,you would have to flip the arrow.

Chapter 3, Problem 45P

Problem

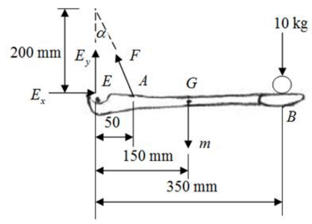
A person is performing slow arm curls with a 10-kg weight as indicated in the figure. The brachialis muscle group (consisting of the biceps and brachi-alis muscles) is the major factor in this exercise. Determine the magnitude *F* of the brachialis-muscle-group force and the magnitude *E* of the elbow joint reaction at point *E* for the forearm position shown in the figure. Take the dimensions shown to locate the effective points of application of the two muscle groups; these points are 200 mm directly above *E* and 50 mm directly to the right of *E*. Include the effect of the 1.5-kg forearm mass with mass center at point *G*. State any assumptions.



Step-by-step solution

Step 1 of 5

Sketch the arm and indicate the forces on it.



α F A G E E_x m E_y 200 mm 350 mm 50 mm 150 mm 10 kg

Step 2 of 5

Calculate the angle made by brachialis group muscle with the vertical reaction force at elbow.

$$\alpha = \tan^{-1}\left(\frac{50}{200}\right)$$
$$= 14.03°$$

Consider the moments on the arm about *E*.

$$\sum M_E = 0$$
$$F\cos\alpha\left(L_{AE}\right) - mg\left(L_{EG}\right) - (10\times g)\left(L_{EB}\right) = 0$$

Here, *F* is the force in the brachialis muscle group, *m* is the mass of the lower arm, L_{AE} is the distance from *A* to *E*, L_{EG} is the distance from *E* to *G*, L_{EB} is the distance from *E* to *B* and g is the acceleration due to gravity.

Substitute $14.03°$ for α, 0.05 m for L_{AE}, 1.5 kg for *m*, 0.15 m for L_{EG}, 0.35 m for L_{EB} and 9.81 m/s^2 for *g*.

$$F\cos 14.03°\times(0.05) - (1.5\times 9.81)(0.15) - (10\times 9.81)(0.35) = 0$$
$$F = 753.317\text{ N}$$

Therefore, the force in the brachialis muscle group, *F*, is $\boxed{753.317\text{ N}}$.

Step 3 of 5

Consider the equilibrium of forces acting on the arm in horizontal direction.

$$\sum F_x = 0$$
$$-F\sin\alpha + E_x = 0$$

Here, E_x is the horizontal component of force at elbow *E*.

Substitute 753.317 N for F, and $14.03°$ for α.

$$-(753)\times\sin 14.04° + E_x = 0$$
$$E_x = 182.75\text{ N}$$

Step 4 of 5

Consider the equilibrium of forces acting on the system in vertical direction.

$$\sum F_y = 0$$
$$F\cos\alpha - mg - 10g + E_y = 0$$

Here, E_y is the vertical component of force at elbow *E*.

Substitute 753.317 N for F, $14.03°$ for α, 1.5 kg for *m* and 9.81 m/s^2 for *g*. .

$$F\cos 14.04° - 1.5\times 9.81 - 10\times 9.81 + E_y = 0$$
$$(753.317)\times\cos 14.04° - 1.5\times 9.81 - 10\times 9.81 + E_y = 0$$
$$E_y = -618\text{ N}$$

Step 5 of 5

Calculate the resultant force at elbow *E*.

$$E = \sqrt{E_x^2 + E_y^2}$$

Substitute 182.75 N for E_x, and -618 N for E_y.

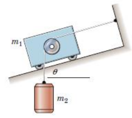
$$R = \sqrt{E_x^2 + E_y^2}$$
$$= \sqrt{182.67^2 + (-618)^2}$$
$$= 644.432\text{ N}$$

Therefore, the resultant force at elbow *E*, is $\boxed{644.432\text{ N}}$.

Chapter 3, Problem 47P

Problem

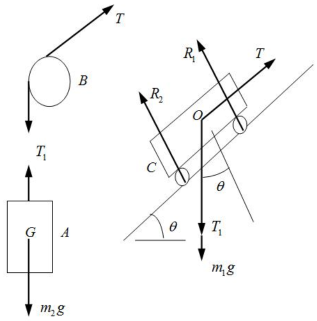
For a given value mj for the cart mass, determine the value *m2* for the cylinder mass which results in equilibrium of the system. Neglect all friction. Evaluate your expression for *9* = 15°, 45°, and 60°.



Step-by-step solution

Step 1 of 6

Draw the free-body diagram of the cylinder A, pulley B, and cart C in positions relative to each other.



Step 2 of 6

Consider the tensions in the rope as shown in the diagram. The cart is lying on an inclined plane. The inclined plane makes an angle θ with the horizontal. Weight of the cart is m_1g acting vertically downwards through the pivot O of the pulley. The line of action of weight m_1g makes an angle θ with normal to the inclined plane. Weight m_2g of the cylinder acts vertically downwards through its center of gravity G along the rope. Reactions on the cart at the wheels are R_1 and R_2 respectively.

Step 3 of 6

When a body under the action of a number of forces is in equilibrium, the algebraic sum of components of the forces along x and y axes as well as algebraic sum of moments of the forces about any point are all zero. Mathematically, $\sum F_x = 0, \sum F_y = 0, \text{ and } \sum M = 0$

Consider the free-body diagram of the cylinder A.

Equate the algebraic sum of the forces in vertical direction to zero.

$$\sum F_V = 0$$
$$T_1 - m_2g = 0$$
$$T_1 = m_2g$$

Consider the free-body diagram of the pulley B of assumed radius, r_B.

Consider the equilibrium of moments about its center.

$$\sum M = 0$$
$$T \times r_B - T_1 \times r_B = 0 .$$
$$T = T_1 = m_2g$$

Step 4 of 6

Consider the free body diagram of the cart C.

Equate the algebraic sum of the forces along the plane to zero.

$$\sum F_P = 0$$
$$T - m_1g\sin\theta - T_1\sin\theta = 0$$

Substitute m_2g for T and T_1.

$$m_2g - m_1g\sin\theta - m_2g\sin\theta = 0$$
$$m_2g(1-\sin\theta) = m_1g\sin\theta$$
$$m_2 = \frac{m_1\sin\theta}{1-\sin\theta}$$

Therefore, the cylinder mass m_2 is $\boxed{\frac{m_1\sin\theta}{1-\sin\theta}}$.

Step 5 of 6

Values of mass m_2 for $\theta = 15°, 45°, \text{ and } 60°$:

Use the obtained relation for mass, m_2.

$$m_2 = \frac{m_1\sin\theta}{1-\sin\theta}$$

Substitute $15°$ for θ.

$$m_2 = \frac{m_1\sin 15°}{1-\sin 15°}$$

Substitute 0.25882 for $\sin 15°$.

$$m_2 = \frac{m_1 \times 0.25882}{1-0.25882}$$
$$= 0.349m_1$$

Step 6 of 6

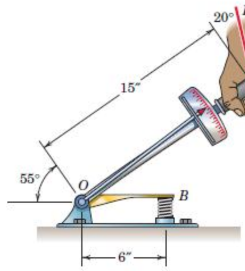
Similarly calculate m_2 for $\theta = 45°$ and $60°$. Arrange the values of m_2 in tabular form.

θ	$\frac{\sin\theta}{1-\sin\theta}$	$m_2 = m_1 \times \frac{\sin\theta}{1-\sin\theta}$
15°	0.349	$0.349m_1$
45°	2.414	$2.414m_1$
60°	6.464	$6.464m_1$

Chapter 3, Problem 48P

Problem

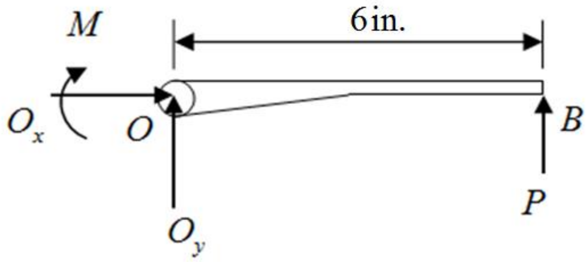
The device shown is used to test automobile-engine valve springs. The torque wrench is directly connected to arm *OB*. The specification for the automotive intake-valve spring is that 83 lb of force should reduce its length from 2 in. (unstressed length) to $1\frac{11}{16}$ in. What is the corresponding reading *M* on the torque wrench, and what force *F* exerted on the torque-wrench handle is required to produce this reading? Neglect the small effects of changes in the angular position of arm *OB*.



Step-by-step solution

Step 1 of 3

Draw the free body diagram of arm *OB*.



Step 2 of 3

Consider the moments about *O* from the free body diagram of arm *OB*.

$$\sum M_O = 0$$
$$P(L_{OB}) - M = 0$$

Here, P is the force acting at *B*, L_{OB} is the length of the arm *OB*, M is the moment at *O*.

Substitute 83 lb for P, 6 in. for L_{OB}.

$$P(L_{OB}) - M = 0$$
$$83 \times (6) - M = 0$$
$$M = 498\text{ lb}\cdot\text{in.}$$
$$= 41.5\text{ lb}\cdot\text{ft}$$

Therefore, the moment acting on the wrench is $\boxed{41.5\text{ lb}\cdot\text{ft}}$.

Comments (1)

Anonymous

Why can you neglect the Force acting at A in step 2? Doesn't it create a moment that should be put in the P(L_ob) -M = 0 equation?

Step 3 of 3

Considering arm *OA* and take moments about *O*.

$$\sum M_O = 0$$
$$F\cos 20^\circ (L_{OA}) - M = 0$$

Here, F is the force exerted on the wrench handle, L_{OA} is the length of the torque wrench.

Substitute $498\text{ lb}\cdot\text{in.}$ for M and 15 in. for L_{OA}.

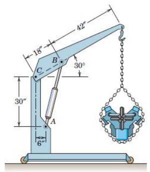
$$F\cos 20^\circ \times (15) - 498 = 0$$
$$F = 35.33\text{ lb}$$

Therefore, the force exerted on the wrench handle is $\boxed{35.33\text{ lb}}$.

Chapter 3, Problem 49P

Problem

The portable floor crane in the automotive shop is lifting a 420-lb engine. For the position shown compute the magnitude of the force supported by the pin at *C* and the oil pressure *p* against the 3.20-in.-diameter piston of the hydraulic-cylinder unit *AB*.

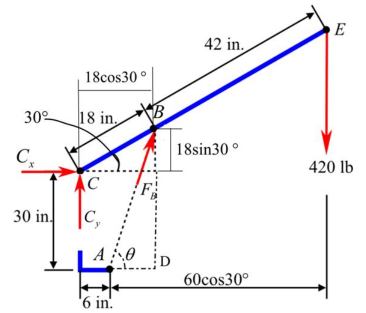


Step-by-step solution

Step 1 of 7

Draw the free body diagram of member *CE*.

Step 2 of 7



Comments (3)

Anonymous
Where did the 60 come from in 60cos30?

Anonymous
Length CDcos30

Anonymous
Sorry, Length CEcos30

Step 3 of 7

Here, C_x is the reaction force in horizontal direction at support *C* and $18\cos 30°$ is the horizontal projection of *CB*.

Step 4 of 7

Calculate the θ using the geometry of triangle *ABD*.

$$\tan\theta = \left(\frac{30+18\sin 30°}{18\cos 30° - 6}\right)$$

$$\theta = \tan^{-1}\left(\frac{30+18\sin 30°}{18\cos 30° - 6}\right) = 76.19°$$

Apply moment equilibrium condition about point *C*.

$$\sum M_C = 0$$

$$F_B \sin\theta(18\cos 30°) - F_B\cos\theta(18\sin 30°) - 420(60\cos 30°) = 0$$

Substitute $76.19°$ for θ.

$$F_B \sin 76.19°(18\cos 30°) - F_B \cos 76.19(18\sin 30°) - 420(60\cos 30°) = 0$$

$$12.99F_B - 21823.84 = 0$$

$$F_B = 1680\,\text{lb}$$

Step 5 of 7

Calculate the Pressure.

$$P = \frac{F_B}{A} = \frac{F_B}{\pi r^2}$$

Here, *r* is the radius of the piston.

Substitute 1.60 in. for r and $1680\,\text{lb}$ for F_B.

$$P = \frac{1680}{\pi(1.60)^2} = 208.9\,\text{lb/in.}^2$$

Therefore, the pressure within the hydraulic cylinder is $\boxed{208.9\,\text{lb/in.}^2}$.

Step 6 of 7

Apply force equilibrium condition in horizontal direction.

$$\sum F_x = 0$$

$$F_B\cos\theta - C_x = 0$$

Substitute $76.19°$ for θ and $1680\,\text{lb}$ for F_B.

$$1680\cos 76.19° - C_x = 0$$

$$C_x = 401\text{ lb}$$

Apply force equilibrium condition in vertical direction.

$$\sum F_y = 0$$

$$F_B\sin\theta - 420 - C_y = 0$$

Substitute $76.19°$ for θ and $1680\,\text{lb}$ for F_B.

$$1680\sin 76.19° - 420 - C_y = 0$$

$$C_y = 1211.44\text{ lb}$$

Comments (1)

Anonymous
Why Cy and Cx are negative in Fx and Fy? As you show in drawing should be positive right?

Step 7 of 7

Calculate the magnitude of the resultant forces at point *C*.

$$C = \sqrt{C_x^2 + C_y^2}$$

Substitute 1211.44 lb for C_y and 401 lb for C_x

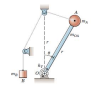
$$C = \sqrt{(401)^2 + (1211.44)^2} = 1276\text{ lb}$$

Therefore, the magnitude of the resultant forces at point *C*is $\boxed{1276\text{ lb}}$.

Chapter 3, Problem 50P

Problem

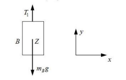
The torsional spring of constant kT = 50 N · m/rad is undeformed when θ = 0. Determine the value(s) of θ over the range 0 ≤ θ ≤ 180° for which equilibrium exists. Use the values mA = 10 kg, mB = 1 kg, mOA = 5 kg, and r = 0.8 m. Assume that OA is a uniform slender rod with a particle A (negligible size) at its end, and neglect the effects of the small ideal rollers.



Step-by-step solution

Step 1 of 13

Draw the free-body diagram of the block B.



Here, $m_B g$ is the weight of cylindrical block B and T_1 is the tension in the string.

Step 2 of 13

Consider the free-body diagram of block B.

Equate the algebraic sum of forces in y direction to zero.

$$\sum F_y = 0$$

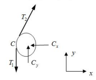
$$T_1 - m_B g = 0$$

$$T_1 = m_B g$$

Step 3 of 13

Consider C and D are the pulleys over which the string passes, which connects the masses A and B respectively.

Draw the free body diagram of pulley C.



Tension in the rope is considered as shown in the diagram.

Step 4 of 13

Consider the radius of pulley C as r_C.

Equate the equilibrium of moments about its center to zero.

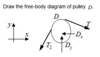
$$\sum M = 0$$

$$T_2 \times r_C - T_1 \times r_C = 0$$

$$T_2 = T_1 = m_B g$$

Step 5 of 13

Draw the free-body diagram of pulley D.



Tension in the rope is considered as shown in the diagram.

Step 6 of 13

Consider the radius of pulley D as r_D.

Equate the equilibrium of moments about its center to zero.

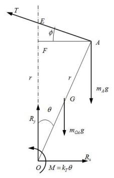
$$\sum M = 0$$

$$T \times r_D - T_2 \times r_D = 0$$

$$T = T_2 = m_B g$$

Step 7 of 13

Draw the free-body diagram of rod OA.



Components of reaction on the rod at pivot O are R_x and R_y in x and y directions respectively. Torsion spring applies a moment $M(=k_T\theta)$ at point O on the rod in anti-clockwise direction. Here θ is in radians. Weight $m_A g$ of point mass A acts vertically downwards, and weight $m_{OA} g$ acts downwards through the Center of gravity, G.

Step 8 of 13

Consider the free body diagram of rod OA.

The height OE of pulley D above hinge O is r. Draw AF perpendicular to OE. Denote angle $\angle EAF$ by ϕ. Note $OA = OE = r$.

Hence,

$$\angle OAE = \angle OEA = \frac{\pi - \theta}{2} = \frac{\pi}{2} - \frac{\theta}{2}$$

From triangle OAF

$$\angle OAF = \pi - \left(\frac{\pi}{2} + \theta\right)$$

$$\angle OAF = \frac{\pi}{2} - \theta$$

Calculate the angle ϕ by using the relation,

$$\phi = \angle EAF = \angle OAE - \angle OAF$$

Substitute $\left(\frac{\pi}{2} - \frac{\theta}{2}\right)$ for $\angle OAE$ and $\left(\frac{\pi}{2} - \theta\right)$ for $\angle OAF$.

$$\phi = \angle EAF = \left(\frac{\pi}{2} - \frac{\theta}{2}\right) - \left(\frac{\pi}{2} - \theta\right)$$

$$\phi = \frac{\theta}{2}$$

Step 9 of 13

When a body under the action of a number of forces is in equilibrium, the resultant force and the resultant couple are both zero. The algebraic sum of components of the forces along x and y axes as well as algebraic sum of moments of the forces about any point are all zero. Mathematically, $\sum F_x = 0, \sum F_y = 0, \text{and} \sum M = 0$.

Step 10 of 13

Equate the sum of the moments of the forces acting on the rod OA about point O to zero

$$\sum M_O = 0$$

$$(T\cos\phi \times r\cos\theta) + (T\sin\phi \times r\sin\theta) + (k_T \times \theta) - (m_A g \times r\sin\theta) - \left(m_{OA} g \times \frac{r}{2}\sin\theta\right) = 0$$

Substitute $\frac{\theta}{2}$ for ϕ.

$$\left(T\cos\frac{\theta}{2} \times r\cos\theta\right) + \left(T\sin\frac{\theta}{2} \times r\sin\theta\right) + (k_T \times \theta) - (m_A g \times r\sin\theta) - \left(m_{OA} g \times \frac{r}{2}\sin\theta\right) = 0$$

Substitute $m_B g$ for T and rearrange the equation.

$$m_B g r \times \left(\cos\theta\cos\frac{\theta}{2} + \sin\theta\sin\frac{\theta}{2}\right) - (gr\sin\theta) \times \left(m_A + \frac{m_{OA}}{2}\right) + (k_T \times \theta) = 0$$

$$\left(m_B g r \times \cos\frac{\theta}{2}\right) - \left(m_A + \frac{m_{OA}}{2}\right) g r \times \sin\theta - (k_T \times \theta) = 0$$

Comments (2)

Anonymous

How did you simply from the second to last line to the very last line of equation?

Anonymous

it's using the identity cos(a-b)=cos(a)cos(b)+sin(a)sin(b)

Step 11 of 13

Substitute $10\,\text{kg}$ for m_A, $1\,\text{kg}$ for m_B, $5\,\text{kg}$ for m_{OA}, $50\,\text{N}\cdot\text{m/rad}$ for k_T, $9.81\,\text{m/s}^2$ for g and $0.8\,\text{m}$ for r.

$$\left\{\begin{array}{l} 1\,\text{kg} \times 9.81\,\text{m/s}^2 \times 0.8\,\text{m} \times \cos\frac{\theta}{2} - \left(10 + \frac{5}{2}\right)\text{kg} \times 9.81\,\text{m/s}^2 \times 0.8\,\text{m} \times \sin\theta \\ + 50\,\text{N}\cdot\text{m/rad} \times \theta \end{array}\right\} = 0$$

Divide both sides by (9.81×0.8) and find the following equation.

$$\cos\frac{\theta}{2} - 12.5\sin\theta + 6.37\theta = 0$$

Write the left hand side as a function $f(\theta)$ of θ.

$$f(\theta) = \cos\frac{\theta}{2} - 12.5\sin\theta + 6.37\theta$$

The values of θ for which $f(\theta)$ is zero are the solutions.

Step 12 of 13

Solve for θ by trial and error method.

Take $\theta = 30^\circ = \frac{\pi}{6}$ as a sample calculation. Thus

$$\begin{aligned} f(30^\circ) &= \cos\left(\frac{30^\circ}{2}\right) - 12.5 \times \sin 30^\circ + 6.37 \times \frac{\pi}{6} \\ &= 0.96593 - 6.25 + 3.33667 \\ &\simeq -1.95 \end{aligned}$$

Thus $\theta = 30^\circ$ is not a solution. Determine values of $f(\theta)$ for different values of θ in a similar way.

Put values of $f(\theta)$ for different values of θ in the tabular form as shown below:

θ	0°	30°	60°	90°	120°	150°	180°
$f(\theta)$	1.00	−1.95	−3.28	−1.78	3.03	10.69	20.02

Step 13 of 13

The value of $f(\theta)$ changes sign between 0° and 30° as well as between 90° and 120°. Thus the value of θ will lie between 0° and 30° as well as between 90° and 120°.

Determine the values of $f(\theta)$ for different values of θ between 0° and 30° as well as between 90° and 120° and put them in tabular form as shown below:

θ	9°	10°	9.4°	100°	104°	103.7°
$f(\theta)$	0.04	−0.06	0.00001	−0.54	0.05	0.007

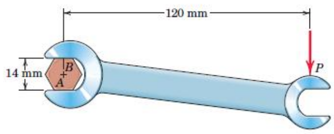
From the table, note that $f(\theta)$ is nearly equal to zero when θ is 9.4° and 103.7°.

Therefore, the values of θ are approximately $\boxed{9.4^\circ}$ and $\boxed{103.7^\circ}$ for which equilibrium exists for the system.

Chapter 3, Problem 51P

Problem

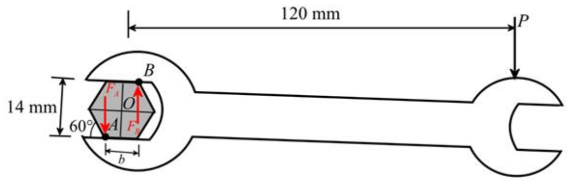
A torque (moment) of 24 N · m is required to turn the bolt about its axis. Determine *P* and the forces between the smooth hardened jaws of the wrench and the corners *A* and *B* of the hexagonal head. Assume that the wrench fits easily on the bolt so that contact is made at corners *A* and *B* only.



Step-by-step solution

Step 1 of 4

Draw the free body diagram of the hexagonal bolt as follows:



Comments (2)

Anonymous
how is the angle of 60 degrees obtained

Anonymous
sum of the angles of a polygon is (n-2)180, where n is the number of sides. 720/6 is 120 and 180-120 is 60

Step 2 of 4

The length of the hexagonal bolt for one side is given as follows:

$$b = \frac{\frac{14\text{ mm}}{2}}{\sin 60°} = 8.083\text{ mm}$$

The force at point *O* is given as follows:

Consider the moment equilibrium condition about *O*.

$$\Sigma M_O = 0$$
$$P(120\text{ mm}) = 24\text{ N}\cdot\text{m}$$
$$P = 0.2\times10^3\text{ N}$$

Therefore, the value of *P* is $\boxed{200\text{ N}}$.

Comments (2)

Anonymous
why 7/sin60?

Anonymous
lol

Step 3 of 4

The equation of moment at point *A* is given as follows:

$$\Sigma M_A = 0$$
$$F_B(8.083\text{ mm}) = (200\text{ N})\left(120\text{ mm} + \left(\frac{8.083\text{ mm}}{2}\right)\right)$$
$$F_B = 3070\text{ N}$$

Therefore, the force at point *B* is $\boxed{3070\text{ N}}$.

Step 4 of 4

Consider the equation of force along vertical direction is given as follows:

$$\Sigma F_y = 0$$
$$F_B - F_A = 200$$

Substitute 3070 N for F_B.

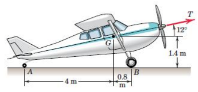
$$3070 - F_A = 200$$
$$F_A = 2870\text{ N}$$

Therefore, the force at point *A* is $\boxed{2870\text{ N}}$.

Chapter 3, Problem 52P

Problem

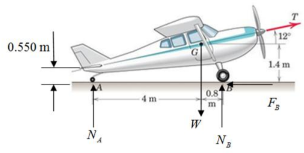
During an engine test on the ground, a propeller thrust T = 3000 N is generated on the 1800-kg airplane with mass center at G. The main wheels at B are locked and do not skid; the small tail wheel at A has no brake. Compute the percent change n in the normal forces at A and B as compared with their "engine-off" values.



Step-by-step solution

Step 1 of 7

Sketch and indicate the forces acting on air plane as in Figure (1).



Comments (4)

Anonymous
where is the 0.550m coming from?

Anonymous
1.4-4*tan(12)

Anonymous
Why do you do 1.4-4*tan(12)? What is the reason behind it?

Anonymous
Draw an imaginary line reflecting the angle 12degree to the opposite side. Now u see that (tan = opp/adj), so 4*tan12 = 1.4 - some number x. -x = 4tan12 - 1.4, so x = 1.4 - 4tan12.

Step 2 of 7

At engine off condition, propeller thrust and frictional force at B is zero.

Consider the moments on the plane about A.

$$\sum M_A = 0$$
$$WL_{AG} - N_B L_{AB} = 0$$

Here, W is the weight of the plane, L_{AG} is the distance horizontal from A to G, L_{AB} is the distance horizontal from A to B, N_B is the normal reaction at wheel B.

Substitute (1800×9.81) N for W, 4 m for L_{AG}, 4.8 m for L_{AB}.

$$(1800 \times 9.81) \times 4 - N_B \times (4.8) = 0$$
$$N_B = 14720 \text{ N}$$

Step 3 of 7

Consider the forces acting on the plane in vertical direction.

$$\sum F_y = 0$$
$$N_A + N_B - W = 0$$

Here, N_A is the normal reaction at wheel A.

Substitute (1800×9.81) N for W, and 14720 N for N_B.

$$N_A + 14720 - (1800 \times 9.81) = 0$$
$$N_A = 2940 \text{ N}$$

Step 4 of 7

Consider the moments on the plane about A.

$$\sum M_A = 0$$
$$WL_{AG} - N'_B L_{AB} + (T \cos 12°)(0.550) = 0$$

Here, T is the propeller thrust, N'_B is the normal reaction at wheel B when engine is ON.

Substitute (1800×9.81) N for W, 3000 N for T, 4 m for L_{AG}, 4.8 m for L_{AB}.

$$(1800 \times 9.81)4 - N'_B \times (4.8) + 3000 \sin 12° \times (0.550) = 0$$
$$N'_B = 15050 \text{ N}$$

Comments (2)

Anonymous
Under the sum of moments equation you use cos 12 but in the calculation you use sin12?

Anonymous
He used cos12 in calculation actually, must have been a typo.

Step 5 of 7

Consider the forces acting on the plane in vertical direction when engine is ON.

$$\sum F_y = 0$$
$$N'_A + N'_B - W + T \sin 12° = 0$$

Here, N'_A is the normal reaction at wheel A when engine is ON.

Substitute (1800×9.81) N for W, 3000 N for T, and 15050 N for N'_B.

$$N'_A + 15050 - (1800 \times 9.81) + 3000 \times \sin 12° = 0$$
$$N'_A = 1983 \text{ N}$$

Step 6 of 7

Consider the percentage change in normal force at A.

$$n_A = \frac{N_A - N'_A}{N_A} \times 100$$

Substitute 1983 N for N'_A, 2940 N for N_A.

$$n_A = \frac{2940 - 1983}{2940} \times 100$$
$$= 32.55\%$$

Therefore, percentage change in normal force at A, n_A, is $\boxed{32.55\%}$

Step 7 of 7

Consider the percentage change in normal force at B.

$$n_B = \frac{N'_B - N_B}{N_B} \times 100$$

Substitute 15050 N for N'_B, 14720 N for N_B.

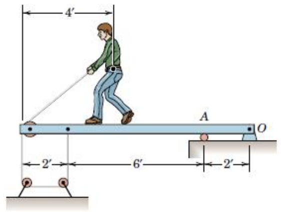
$$n_B = \frac{15050 - 14720}{14720} \times 100$$
$$= 2.28\%$$

Therefore, percentage change in normal force at B, n_B, is $\boxed{2.28\%}$.

Chapter 3, Problem 53P

Problem

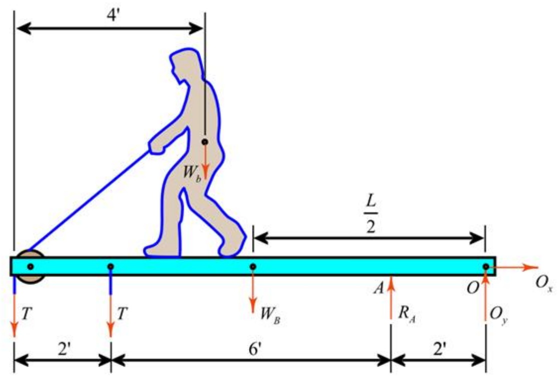
To test the deflection of the uniform 200-lb beam the 120-lb boy exerts a pull of 40 lb on the rope rigged as shown. Compute the force supported by the pin at the hinge *O*.



Step-by-step solution

Step 1 of 4

Draw the free body diagram treating the boy, the beam, and the pully connected to the beam as the system as shown in the figure,



Step 2 of 4

Apply moment equilibrium about point *O* to find the reaction force at roller support *A*.

$$\sum M_O = 0;$$
$$T(2+6+2)+T(2+6)+W_b(2+6+2-4)+W_B\left(\frac{L}{2}\right)-R_A(2)=0$$

Here, tension in the rope is T, weight of the boy is W_b, weight of the beam is W_B, and length of the beam is L.

Substitute $40\,\text{lb}$ for T, $120\,\text{lb}$ for W_b, $200\,\text{lb}$ for W_B, and $10\,\text{ft}$ for L.

$$40(2+6+2)+40(2+6)+120(2+6+2-4)+200\left(\frac{10}{2}\right)-R_A(2)=0$$
$$R_A = 1220\,\text{lb}$$

Step 3 of 4

Apply force equilibrium along horizontal direction to find the horizontal component of the reaction force at hinge *O*.

O_y $$\sum F_x = 0;$$
$$O_x = 0$$

Apply force equilibrium along vertical direction to find the vertical component of the reaction force at hinge *O*.

$$\sum F_y = 0;$$
$$-T-T-W_b-W_B+R_A+O_y=0$$
$$-40-40-120-200+1220+O_y=0$$
$$O_y=-820\,\text{lb}$$

Here, the negative sign indicates the upward direction of the force used in the free body diagram is incorrect and the actual direction is downwards.

Step 4 of 4

Find the force supported by the hinge *O* using the formula,

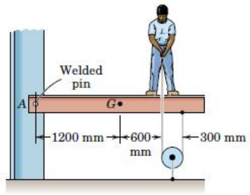
$$R_O=\sqrt{O_x^2+O_y^2}$$
$$=\sqrt{0^2+(-820)^2}$$
$$=820\,\text{lb}$$

Therefore, the force supported by the hinge *O* is $\boxed{820\,\text{lb}}$.

Chapter 3, Problem 54P

Problem

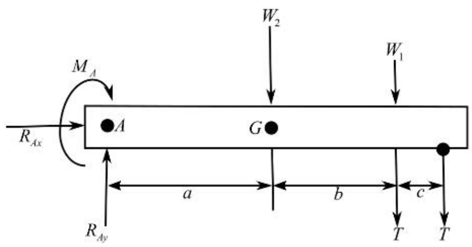
The pin A, which connects the 200-kg steel beam with center of gravity at *G* to the vertical column, is welded both to the beam and to the column. To test the weld, the 80-kg man loads the beam by exerting a 300-N force on the rope which passes through a hole in the beam as shown. Calculate the torque (couple) *M* supported by the pin.



Step-by-step solution

Step 1 of 3

Draw the free body diagram of the steel beam.



Comments (2)

Anonymous
Why are there two tensions? Isn't the cable one continuous whole?

Anonymous
I think there should be only one tension, it says in the problem that the wire "passes through"

Step 2 of 3

Calculate the weight of the man.

$$W_1 = m_1 g$$

Here, W_1 is weight of man and m_1 is the mass of the man.

Substitute 80 kg for m_1, 9.81 m/s^2 for g.

$$W_1 = (80\text{ kg})(9.81\text{ m/s}^2)$$
$$= 784.8\text{ N}$$

Calculate the force due to weight of the beam.

$$W_2 = m_2 g$$

Here, W_2 is weight of the beam and m_2 is the mass of the beam.

Substitute 200 kg for m_2 and 9.81 m/s^2 for g.

$$W_2 = (200\text{ kg})(9.81\text{ m/s}^2)$$
$$= 1962\text{ N}$$

Step 3 of 3

Consider the moment of all the forces about the point *A* and write the moment equilibrium equation.

$$\sum M_A = 0$$
$$M - W_2(a) + W_1(a+b) + T(a+b) + T(a+b+c) = 0$$
$$M = W_2(a) + W_1(a+b) + T(a+b) + T(a+b+c)$$

Here, M is the torque/moment reaction at point *A*.

Substitute 1962 N for W_2, 785 N for W_1, 300 N for T and 1200 mm for a, 600 mm for b, 300 mm for *c*.

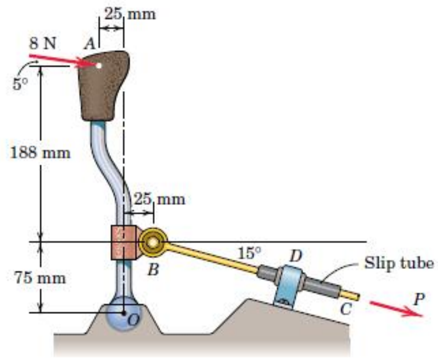
$$M = \begin{bmatrix} (1962\text{ N})(1200\text{ mm}) + (785\text{ N})(1200\text{ mm} + 600\text{ mm}) \\ +(300\text{ N})(1200\text{ mm} + 600\text{ mm}) + (300\text{ N})(1200\text{ mm} + 600\text{ mm} + 300\text{ mm}) \end{bmatrix}$$
$$= 4.94 \times 10^6\text{ N}\cdot\text{mm}\left(\frac{10^{-3}\text{ m}}{1\text{ mm}}\right)$$
$$= 4.94\text{ kN}\cdot\text{m}$$

Therefore, the torque (couple) supported by the pin is $\boxed{4.94\text{ kN}\cdot\text{m}}$.

Chapter 3, Problem 55P

Problem

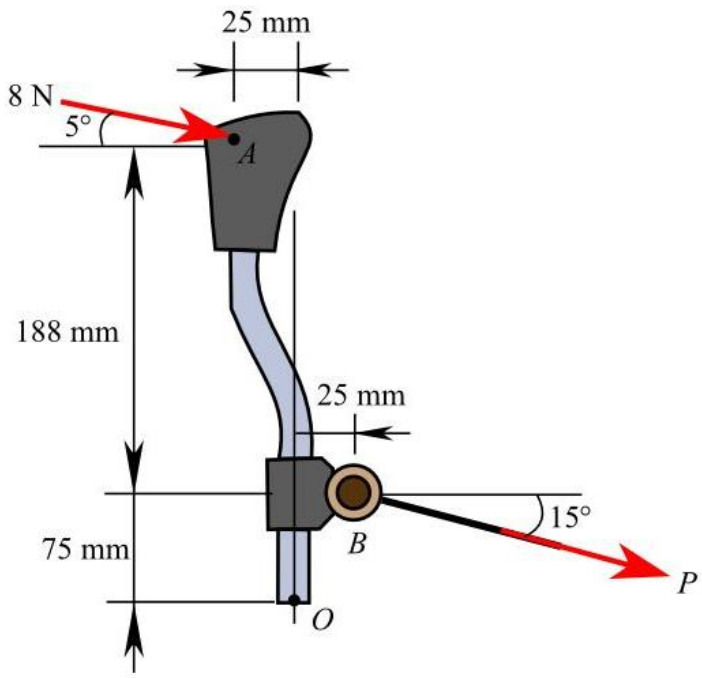
A portion of the shifter mechanism for a manual car transmission is shown in the figure. For the 8-N force exerted on the shift knob, determine the corresponding force P exerted by the shift link BC on the transmission (not shown). Neglect friction in the ball-and-socket joint at O, in the joint at B, and in the slip tube near support D. Note that a soft rubber bushing at D allows the slip tube to self-align with link BC.



Step-by-step solution

Step 1 of 2

Draw the free body diagram of the shifter mechanism.



Step 2 of 2

Calculate the force P exerted by the shift link BC.

Take moment at point at joint O.

$$\sum M_O = 0$$

$$8\sin 5°(25) - 8\cos 5°(188+75) - P\cos 15°(75) - P\sin 15°(25) = 0$$

$$-2078.56 - 78.91P = 0$$

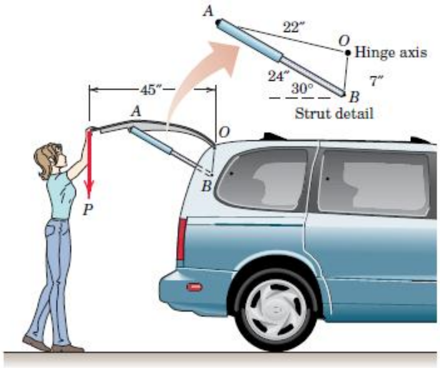
$$P = 26.3\,\text{N}$$

Therefore, the force P exerted by the shift link BC is $\boxed{26.3\,\text{N}}$.

Chapter 3, Problem 57P

Problem

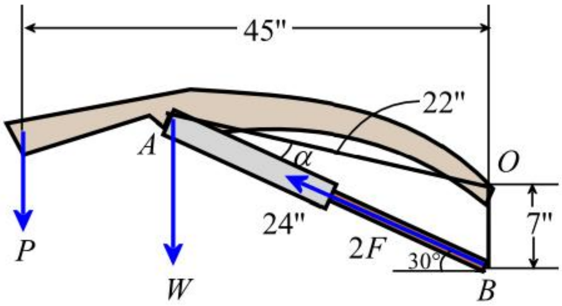
It is desired that a person be able to begin closing the van hatch from the open position shown with a 10-lb vertical force *P*. As a design exercise, determine the necessary force in each of the two hydraulic struts *AB*. The center of gravity of the 90-lb door is 1.5 in. directly below point *A*. Treat the problem as two-dimensional.



Step-by-step solution

Step 1 of 3

Draw the free body diagram of the linkage.



Step 2 of 3

Apply the cosine rule to the triangle ABO.

$OB^2 = OA^2 + AB^2 - 2(OA)(AB)\cos\alpha$

Here, the lengths of the links are *OA*, *AB*, and the angle is α.

Substitute 7 in. for OB, 22 in. for OA, and 24 in. for AB.

$7^2 = 22^2 + 24^2 - 2(22)(24)\cos\alpha$

$\cos\alpha = 0.9574$

$\alpha = 16.79°$

Step 3 of 3

Consider the moment about point *O*.

$\sum M_O = 0$

$P(45) - 2F(22\sin\alpha) + W(22\times\cos(30° - \alpha)) = 0$

Here, the force applied is *P*, the force exerted in each strut is *F*, and the weight is *W*.

Substitute 10 lb for P, 90 lb for W, and $16.79°$ for α.

$(10\times 45) - 2F(22\sin 16.79°) + (90\times 22\times\cos(30° - 16.79°)) = 0$

$450 - 12.71F + 1927.61 = 0$

$12.71F = 2377.61$

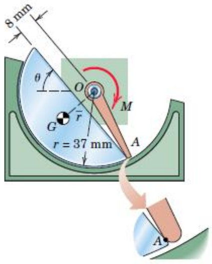
$F = 187.1\text{ lb}$

Therefore, the force exerted on each strut is $\boxed{187.1\text{ lb}}$.

Chapter 3, Problem 58P

Problem

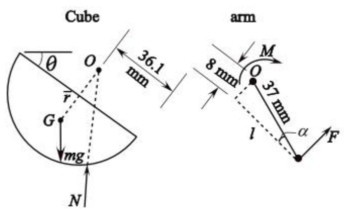
Certain elements of an in-refrigerator ice-cube maker are shown in the figure. (A “cube” has the form of a cylindrical segment!) Once the cube freezes and a small heater (not shown) forms a thin film of water between the cube and supporting surface, a motor rotates the ejector arm *OA* to remove the cube. If there are eight cubes and eight arms, determine the required torque *M* as a function of *θ*. The mass of eight cubes is 0.25 kg, and the center-of-mass distance $\bar{r} = 0.55r$. Neglect friction, and assume that the resultant of the distributed normal force acting on the cube passes through point *O*.



Step-by-step solution

Step 1 of 3

Draw the schematic diagram.



Step 2 of 3

Calculate the length *l*.

Apply Pythagoras theorem.

$$l = \sqrt{37^2 - 8^2}$$
$$= 36.1 \text{ mm}$$

Take the moments about point *O*.

Consider the cube diagram.

$$\sum M_O = 0$$
$$mg\bar{r}\sin\theta - lF = 0$$

Here, *m* is the mass of the ice cube, $\bar{r}$ is the distance from the centroid, and *g* is the acceleration due to gravity.

Substitute 0.25kg for *m*, 9.81 m/s^2 for *g*, 36.1 mm for *l*, and $0.55r$ for $\bar{r}$.

$$(0.25\times 9.81)0.55r\sin\theta - 36.1F = 0$$

Substitute 37mm for *r*

$$(0.25\times 9.81)0.55\times 37\sin\theta - 36.1F = 0$$
$$49.9\sin\theta - 36.1F = 0$$
$$F = \frac{49.9\sin\theta}{36.1}$$
$$= 1.382\sin\theta$$

Comments (1)

Anonymous

mgr'sintheta ? how did we get that

Step 3 of 3

Calculate the required torque *M* as a function of θ.

Take the moments about point *O*.

Consider the arm diagram.

$$\sum M_O = 0$$
$$-M + lF = 0$$

Substitute $1.382\sin\theta$ for *F*, and 36.1 mm for *l*.

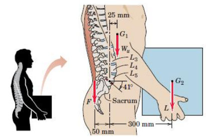
$$-M + 36.1(1.382\sin\theta) = 0$$
$$M = 49.9\sin\theta \text{ N.mm}$$

Hence, the required torque *M* as a function of θ is $\boxed{49.9\sin\theta \text{ N.mm}}$.

Chapter 3, Problem 59P

Problem

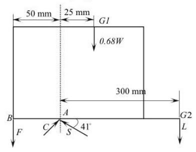
The lumbar portion of the human spine supports the entire weight of the upper torso and the force load imposed on it. We consider here the disk (shaded red) between the lowest vertebra of the lumbar region (*L*5) and the uppermost vertebra of the sacrum region. (*a*) For the case *L* = 0, determine the compressive force *C* and the shear force S supported by this disk in terms of the body weight W. The weight *Wu* of the upper torso (above the disk in question) is 68% of the total body weight *W* and acts at *Gi*. The vertical force *F* which the rectus muscles of the back exert on the upper torso acts as shown in the figure. (*b*) Repeat for the case when the person holds a weight of magnitude *L* = *W*/3 as shown. State any assumptions.



Step-by-step solution

Step 1 of 8

Draw the free body diagram.



Step 2 of 8

Consider the free body diagram.

Write the force vectors.

$$\mathrm{F} = -F\mathbf{j}$$

Here, F is the force acting on the point B.

Calculate the compressive force vector.

$$\mathbf{C} = C\left(\sin 41^\circ\right)\mathbf{i} + C\left(\cos 41^\circ\right)\mathbf{j}$$

Here, C is the compression force, and $\mathbf{C}$ is the compression force vector.

Calculate the shear force vector.

$$\mathbf{S} = -S\left(\cos 41^\circ\right)\mathbf{i} + \mathrm{S}\left(\sin 41^\circ\right)\mathbf{j}$$

Here, S is the shear force, and $\mathbf{S}$ is the shear force vector.

Calculate the force vector at point $G2$.

$$F_{G2} = -L\mathbf{j}$$

Here, F_{G2} is the force vector acting on the point $G2$, and L is the force vector at point $G2$.

Step 3 of 8

Take moment about point A.

$$\sum M_A = 0$$
$$0.68W \times 25\,\text{mm} - F_B \times 50\,\text{mm} + L \times 300\,\text{mm} = 0$$

Here, M_A is the moment about A, $0.68W$ is the weight on the point G_1, .

Substitute F for F_B.

$$0.68W \times 25\,\text{mm} - F \times 50\,\text{mm} + L \times 300\,\text{mm} = 0$$
$$F \times 50\,\text{mm} = \left(17W + 300L\right)\text{mm}$$
$$F = \frac{\left(17W + 300L\right)\text{mm}}{50\,\text{mm}}$$
$$= 0.34W + 6L$$

Step 4 of 8

Resolve forces vertically from the free body diagram.

$$-F + \mathbf{C} + \mathbf{S} - 0.68W + F_{G2} = 0$$

Substitute $\left(0.34W + 6L\right)\mathbf{j}$ for F, $C\left(\sin 41^\circ\right)\mathbf{i} + C\left(\cos 41^\circ\right)\mathbf{j}$ for $\mathbf{C}$, $-S\left(\cos 41^\circ\right)\mathbf{i} + \mathrm{S}\left(\sin 41^\circ\right)\mathbf{j}$ for $\mathbf{S}$, and $-L\mathbf{j}$ for F_{G2}.

$$\left(0.34W + 6L\right)\mathbf{j} + C\left(\sin 41^\circ\right)\mathbf{i} + C\left(\cos 41^\circ\right)\mathbf{j} + -S\left(\cos 41^\circ\right)\mathbf{i} + \mathrm{S}\left(\sin 41^\circ\right)\mathbf{j}0.68W\mathbf{j} + L\mathbf{j} = 0$$
$$\left(0.656C - 0.755S\right)\mathbf{i} + \left(0.755C + 0.656S + 1.02W + 7L\right)\mathbf{j} = 0$$

Evaluate the x, and y components from the above equation.

$$\left(0.656C - 0.755S\right) = 0$$
$$C = \frac{0.755S}{0.656} \quad \text{...... (1)}$$
$$= 1.15S$$

Equate the y components.

$$\left(0.755C + 0.656S + 1.02W + 7L\right) = 0 \quad \text{...... (2)}$$

Step 5 of 8

Substitute $1.15S$ for C in the equation (2).

$$\left(0.755C + 0.656S + 1.02W + 7L\right) = 0$$
$$\left(0.755\left(1.15S\right) + 0.656S + 1.02W + 7L\right) = 0$$
$$S = \frac{-7L - 1.02W}{1.525} \quad \text{...... (3)}$$
$$= -4.59L - 0.6688W$$

Substitute $-4.59L - 0.6688W$ for S in the equation (1).

$$C = 1.15S$$
$$= 1.15\left(-4.59L - 0.6688W\right) \quad \text{...... (4)}$$
$$= -5.28L - 0.769W$$

a)

Step 6 of 8

Substitute 0 for L in the equation (3).

$$S = -4.59L - 0.6688W$$
$$= -4.59\left(0\right) - 0.6688W$$
$$= -0.6688W$$

Substitute 0 for L in the equation (4).

$$C = -5.28L - 0.769W$$
$$= -5.28\left(0\right) - 0.769W$$
$$= -0.769W$$

Hence, the shear force is $\boxed{0.6688W}$, and the compression force is $\boxed{0.769W}$.

Step 7 of 8

b) Substitute $\frac{W}{3}$ for L in the equation (3).

$$S = -4.59L - 0.6688W$$
$$= -4.59\left(\frac{W}{3}\right) - 0.6688W$$
$$= -1.53W - 0.6688W$$
$$= -2.2W$$

Substitute $\frac{W}{3}$ for L in the equation (4).

$$C = -5.28L - 0.769W$$
$$= -5.28\left(\frac{W}{3}\right) - 0.769W$$
$$= -2.53W$$

Hence, the shear force is $\boxed{2.2W}$, and the compression force is $\boxed{0.769W}$.

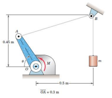
Step 8 of 8

Here, $-$ sign indicates the direction of the force.

Chapter 3, Problem 60P

Problem

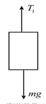
Determine and plot the moment *M* which much be applied to the crank *OA* in order to hold the cylinder of mass $m = 5$ kg in equilibrium. Neglect the effects of the mass of *OA* and friction and consider the range $0 \le \theta \le 180°$. State the maximum and minimum values of the absolute value of *M* and the values of θ for which these extremes occur, and physically justify these results.



Step-by-step solution

Step 1 of 15

Draw the free-body diagram of the cylinder.



Weight mg of the cylinder acts vertically downwards and tension *T*1 acts upwards.

Step 2 of 15

Equate the algebraic sum of the forces acting on the cylinder in vertical direction to zero.

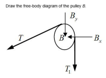
$\sum F_Y = 0$.

$T_1 - mg = 0$

$T_1 = mg$

Step 3 of 15

Draw the free-body diagram of the pulley *B*.



Tensions in the rope are shown in the diagram.

Step 4 of 15

Equate the equilibrium of moments of pulley *B* about its center to zero.

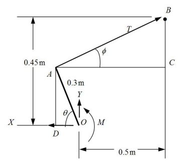
$\sum M = 0$.

$T \times r_B - T_1 \times r_B = 0$

$T = T_1 = mg$

Step 5 of 15

Draw free-body diagram of the crank OA.



Step 6 of 15

Components of reaction on the crank at pivot O are X and Y in horizontal and vertical directions. Moment M applied at point O on the crank is in counter-clockwise direction.

Draw AC perpendicular to the vertical line *BC* through *A* and AD perpendicular to the horizontal line through O. Denote the angle $\angle BAC$ by ϕ.

Express AC, BC and AB in terms of given dimensions and mark angle θ.

$$\begin{aligned} AC &= 0.5\,\text{m} + OD \\ &= 0.5\,\text{m} + OA\cos\theta \\ &= (0.5 + 0.3\cos\theta)\,\text{m} \end{aligned}$$

$$\begin{aligned} BC &= 0.45\,\text{m} - AD \\ &= 0.45\,\text{m} - OA\sin\theta \\ &= (0.45 - 0.3\sin\theta)\,\text{m} \end{aligned}$$

$$\begin{aligned} AB &= \sqrt{AC^2 + BC^2} \\ &= \sqrt{(0.5+0.3\cos\theta)^2 + (0.45-0.3\sin\theta)^2}\,\text{m} \\ &= \sqrt{0.5425 + 0.3\cos\theta - 0.27\sin\theta}\,\text{m} \end{aligned}$$

Step 7 of 15

Hence,

$$\cos\phi = \frac{(0.5+0.3\cos\theta)}{\sqrt{0.5425+0.3\cos\theta-0.27\sin\theta}} \quad \ldots\ldots (1)$$

$$\sin\phi = \frac{(0.45-0.3\sin\theta)}{\sqrt{0.5425+0.3\cos\theta-0.27\sin\theta}} \quad \ldots\ldots (2)$$

$$\tan\phi = \frac{(0.45-0.3\sin\theta)}{(0.5+0.3\cos\theta)}$$

Step 8 of 15

Consider the free-body diagram of the crank OA and equate the sum of moments of the forces acting on OA about point O to zero. $\sum M_O = 0$

$M - T\cos\phi \times 0.3\,\text{m} \times \sin\theta - T\sin\phi \times 0.3\,\text{m} \times \cos\theta = 0$

$M = 0.3T \times (\sin\theta\cos\phi + \cos\theta\sin\phi) \times 1\,\text{m}$ ...... (3)

Substitute equations (1) and (2) in (3) and *mg* for *T*

$$\begin{aligned} M &= 0.3mg \times \left\{ \left[\sin\theta \times \frac{0.5+0.3\cos\theta}{\sqrt{0.5425+0.3\cos\theta-0.27\sin\theta}}\right] + \left[\cos\theta \times \frac{0.45-0.3\sin\theta}{\sqrt{0.5425+0.3\cos\theta-0.27\sin\theta}}\right] \right\} \times 1\,\text{m} \\ &= 0.3mg \times \frac{(0.5\sin\theta + 0.45\cos\theta)}{\sqrt{0.5425+0.3\cos\theta-0.27\sin\theta}} \times 1\,\text{m} \end{aligned}$$

Step 9 of 15

Substitute $5\,\text{kg}$ for m and $9.81\,\text{m/s}^2$ for g.

$$\begin{aligned} M &= 0.3 \times 5\,\text{kg} \times 9.81\,\text{m/s}^2 \times \frac{(0.5\sin\theta+0.45\cos\theta)}{\sqrt{0.5425+0.3\cos\theta-0.27\sin\theta}} \times 1\,\text{m} \\ &= 14.715 \times \frac{(0.5\sin\theta+0.45\cos\theta)}{\sqrt{0.5425+0.3\cos\theta-0.27\sin\theta}}\,\text{N}\cdot\text{m} \end{aligned}$$

The moment to be applied at the crank is $\boxed{14.715 \times \frac{(0.5\sin\theta+0.45\cos\theta)}{\sqrt{0.5425+0.3\cos\theta-0.27\sin\theta}}\,\text{N}\cdot\text{m}}$ to hold the cylinder in equilibrium for any crank angle θ.

Step 10 of 15

Determine the values of M for different values of θ in the range of $0 \le \theta \le 180°$.

Take $\theta = 60°$ as a sample calculation.

Calculate the corresponding value of M as given below.

$$M = 14.715 \times \frac{(0.5\sin\theta+0.45\cos\theta)}{\sqrt{0.5425+0.3\cos\theta-0.27\sin\theta}}\,\text{N}\cdot\text{m}$$

Substitute $60°$ for θ to find the corresponding value of M.

$$\begin{aligned} M &= 14.715 \times \frac{(0.5\sin 60° + 0.45\cos 60°)}{\sqrt{0.5425+0.3\cos 60° - 0.27\sin 60°}}\,\text{N}\cdot\text{m} \\ &= 14.715 \times \frac{(0.433015+0.225)}{\sqrt{0.5425+0.15-0.2338281}}\,\text{N}\cdot\text{m} \\ &= 14.297\,\text{N}\cdot\text{m} \end{aligned}$$

Step 11 of 15

Find the values of M for other values of θ and note them in a tabular form.

θ (deg)	$(0.5\sin\theta+0.45\cos\theta)$	$\sqrt{0.5425+0.3\cos\theta-0.27\sin\theta}$	M (N·m)
0	0.45	0.918	7.21
30	0.64	0.817	11.5
45	0.672	0.751	13.17
60	0.658	0.677	14.29
70	0.624	0.626	14.67

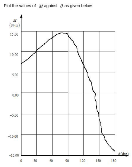
Step 12 of 15

Similarly tabulate rest of the values up to 180 degrees.

θ (deg)	$(0.5\sin\theta+0.45\cos\theta)$	$\sqrt{0.5425+0.3\cos\theta-0.27\sin\theta}$	M (N·m)
75	0.599	0.599	14.71
80	0.57	0.573	14.64
90	0.5	0.522	14.09
120	0.208	0.398	7.68
150	−0.1397	0.384	−5.35
180	−0.45	0.492	−13.45

Step 13 of 15

Plot the values of M against θ as given below:



Step 14 of 15

From the plot, note that the maximum and minimum values of the absolute values of M are $14.71\,\text{N}\cdot\text{m}$ and $0\,\text{N}\cdot\text{m}$ respectively. The corresponding values of θ are approximately $75°$ and $138°$.

Therefore, the maximum absolute value of M is $\boxed{14.71\,\text{N}\cdot\text{m}}$ at $\boxed{75°}$ and minimum absolute value of *M* is $\boxed{0\,\text{N}\cdot\text{m}}$ at $\boxed{138°}$.

Justification of the results:

Determine angle ϕ when the angle θ is $75°$ by using the following formula.

$$\begin{aligned} \tan\phi &= \frac{0.45-0.3\sin\theta}{0.5+0.3\cos\theta} \\ &= \frac{0.45-0.3\sin 75°}{0.5+0.3\cos 75°} \\ &= 0.27737 \end{aligned}$$

$$\begin{aligned} \phi &= \tan^{-1}(0.27737) \\ &= 15.5° \end{aligned}$$

Step 15 of 15

Consider the angle $\angle AOB$.

$\angle AOB = \theta + \phi = 75° + 15.5° = 90.5°$

Thus the rope is nearly perpendicular to the crank and the moment applied on the crank by tension in the rope is maximum. So the applied moment in opposite direction is also maximum.

Similarly find the angle ϕ when θ is $138°$. In this position the acute angle between OA and AC is given by $(180° - 138°)$, that is $42°$. Determine the corresponding angle ϕ by using the following formula.

$$\begin{aligned} \tan\phi &= \frac{0.45-0.\sin 42°}{0.5-0.3\cos 42°} \\ &= \frac{0.249261}{0.277058} \\ &= 0.9 \end{aligned}$$

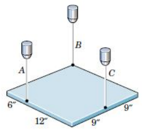
$$\begin{aligned} \phi &= \tan^{-1}(0.9) \\ &= 15.541.987° \end{aligned}$$

Thus the rope and the crank become more or less aligned. Hence the moment applied on the crank by the tension in the rope is zero. So the applied moment is also zero.

Chapter 3, Problem 61P

Problem

A uniform steel plate 18 in. square weighing 68 lb is suspended in the horizontal plane by the three vertical wires as shown. Calculate the tension in each wire.



Step-by-step solution

Step 1 of 5

Consider the moments about *x*-axis.

$$\sum M_x = 0:$$
$$T_A(L_1) + T_C(L_3) - W(L_G) = 0$$

Here, T_A is the tension in wire *A*, T_C is the tension in wire *C*, W is the weight of the plate, L_1 is the distance from line of action of T_A to *x*-axis, L_3 is the distance from line of action of T_C to *x*-axis, and L_G is the distance from line of action of *W* to *x*-axis.

Substitute 6 in for L_1, 18 in for L_3, 9 in for L_G, and 68 lb for *W*.

$$6T_A + 18T_C - 68\times(9) = 0$$
$$T_A + 3T_C = 102 \quad \text{...... (1)}$$

Step 2 of 5

Consider the moments about *y*-axis.

$$\sum M_y = 0:$$
$$-T_A(l_1) - T_C(l_3) + W(l_G) = 0$$

Here, l_1 is the distance from line of action of T_A to *y*-axis and l_3 is the distance from line of action of T_C to *y*-axis.

Substitute 18 in for l_1, 9 in for l_3, 9 in for l_G, and 68 lb for *W*.

$$-18T_A - 9T_C + 68\times(9) = 0$$
$$2T_A + T_C = 68 \quad \text{...... (2)}$$

Step 3 of 5

Calculate the tension in wires.

Solve equations (1) and (2).

$$5T_C = 136$$
$$T_C = 27.2\text{ lb}$$

Therefore, tension in wire *C* is $\boxed{27.2\text{ lb}}$.

Comments (5)

Anonymous
Where did this equation come from??

Anonymous
he simplified it from the previous steps to have smaller numbers

Anonymous
where did the 5Tc come from?

Anonymous
Set equations from Step 1 and Step 2 equal--(T_a +3c-102) = (2T_a + T_c - 68). You end up with (T_a = 2T_c-34). Use this substitution in Sum-of-moments_x. You end up with 5T_c = 136.

Anonymous
18 distance is for T(B), not T(A)

Step 4 of 5

Calculate the tension in wire *A*.

Substitute 27.2 lb for T_C in equation (1).

$$T_A + 3T_C = 102$$
$$T_A + 3(27.2) = 102$$
$$T_A = 20.4\text{ lb}$$

Therefore, tension in wire *A* is $\boxed{20.4\text{ lb}}$.

Step 5 of 5

Consider the forces acting in *z*-direction.

$$\sum F_z = 0:$$
$$T_A + T_B + T_C - W = 0$$

Here, T_B is the tension in wire *B*.

Substitute 27.2 lb for T_C, 20.4 lb for T_A, 68 lb for *W*.

$$20.4 + T_B + 27.2 - 68 = 0$$
$$T_B = 20.4\text{ lb}$$

Therefore, tension in wire *B* is $\boxed{20.4\text{ lb}}$.

Comments (4)

Anonymous
Why isn't the force of the plate 68 lbs x gravity?

Anonymous
Because it was already in lb which is a force if it was grams you would have to convert i think.

Anonymous
why are forces a and c considered on x and y? what about b?

Anonymous
they are along the line of action so therefore do not produce moment