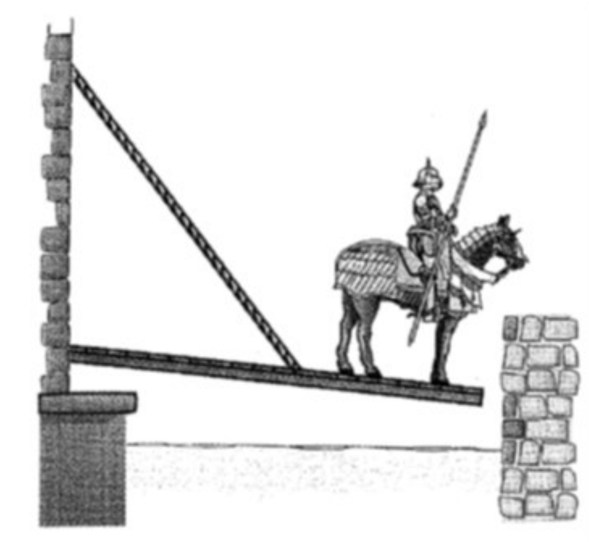
Week 2 CHW Solutions

Sir Lance a Lost's new draw bridge was designed poorly and stops at an angle of 20° below the horizontal. Sir Lost and his steed stop when their combined center of mass is 1.0 m from the end of the bridge. The bridge is 8.0 m long and has a mass of 2000 kg; the lift cable is attached to the bridge 5.0 m from the castle end and to a point 12 m above the bridge. Sir Lost's mass combined with his armor and steed is 1000 kg.

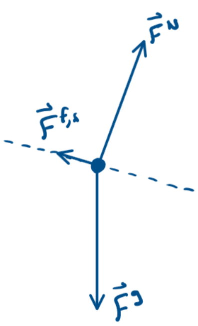


(a) Use the related quantities sensemaking technique to compare the combined gravitational force acting on Sir Lance a Lost, his armor, and his steed (treat these as one object) with the normal and frictional forces from the bridge acting on his steed, by answering the following prompts.
- Draw a free body diagram for the combined object. The diagram should include the gravitational force, the normal force, and the frictional force.
- What relationship do you expect to exist between the gravitational force and the combined normal and frictional forces? Explain.
- If you were asked to find the combined normal force and frictional force **from** Sir Lance a Lost **on** the bridge, what quantity would you use? Explain.

(b) Determine the tension in the cable.

(c) Find the horizontal and vertical force components acting on the bridge at the castle end.

(a)



The force of friction + normal force from bridge on steed are, combined, equal and opposite to the gravitational force from Earth on steed. This is due to the system being in static equilibrium, therefore $\Sigma \vec F_{on\ s} = 0$.

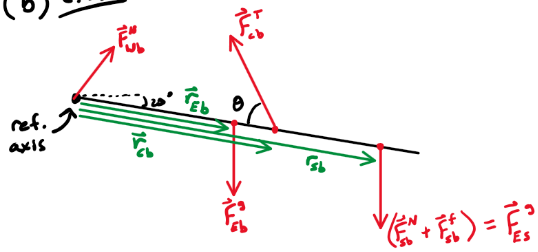
$\Rightarrow \vec F^f_{bs} + \vec F^N_{bs} = -\vec F^g_{Es} = -\underbrace{\left(\vec F^f_{sb} + \vec F^N_{sb}\right)}_{\text{third law force pairs}}$

b/c 3rd law force pairs are equal & opposite, $\vec F^N_{sb} = -\vec F^N_{bs}$.

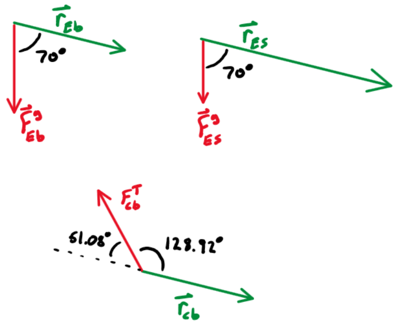
Therefore, $\vec F^f_{sb} + \vec F^N_{sb} = \vec F^g_{Es}$

and $\left|\vec F^f_{sb} + \vec F^N_{sb}\right| = m_s g = (1000\ kg)(9.8\ m/s^2)$

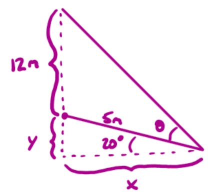
(b) eFBD



vector operation diagrams



an aside for geometry



$\sin 20° = \frac{y}{5m}$

$y = 1.71\ m$

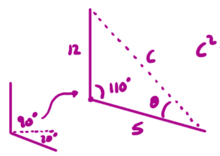
$\cos 20° = \frac{x}{5m}$

$x = 4.70m$

$\Rightarrow \tan(\theta + 20°) = \frac{12 + y}{x}$

$\Rightarrow \theta = 51.08°$

or, if you would like to use the law of cosines twice:



$c^2 = 5^2 + 12^2 - 2(5)(12)\cos 110°$

$c = 14.49$

$\Downarrow$

$12^2 = 5^2 + (14.49)^2 - 2(5)(14.49)\cos\theta$

$\theta = 51.08°$

$$\Sigma \tau = I \cancel{\alpha}^{\,0}$$

$$\tau_{cb} + \tau_{Eb} + \tau_{Es} + \tau_{wb} = 0$$

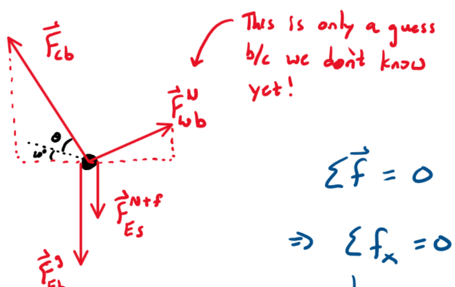
$$|\vec{r}_{cb}||\vec{F}_{cb}| \sin 128.9° - |\vec{r}_{Eb}||\vec{F}_{Eb}| \sin 70° - |\vec{r}_{Es}||\vec{F}_{Es}| \sin 70° + |\cancel{\vec{r}_{wb}}^{\,0}||\vec{F}_{wb}| \sin(?) = 0$$

b/c we chose our reference axis at the wall, this torque is zero!

$$(5m)|\vec{F}_{cb}| \sin 128.9° - (4m)(2000kg)(9.8m/s^2)\sin 70° - (7m)(1000kg)(9.8m/s^2)\sin 70° = 0$$

$$|\vec{F}^T_{cb}| = 35{,}510\ N$$

(c)



static translational equilibrium

$$\Sigma \vec{F} = 0$$

$$\Rightarrow \Sigma F_x = 0 \quad \text{and} \quad \Sigma F_y = 0$$

$$F_{cbx} + F_{wbx} = 0$$

$$-|\vec{F}_{cb}| \cos(51.08° + 20°) + F_{wbx} = 0$$

$$F_{wbx} = +11{,}514\ N$$

$$F_{cby} + F^g_{Eb} + F^{N+f}_{Es} + F^N_{wb} = 0$$

$$|\vec{F}_{cb}| \sin(51.08° + 20°) - m_b g - m_s g + F^N_{wb} = 0$$

$$F^N_{wb} = -4{,}191\ N$$