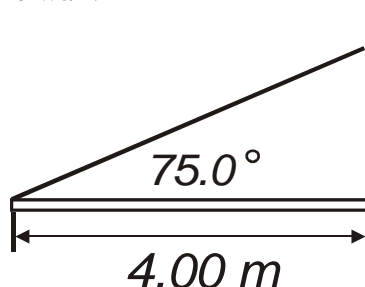


AP Physics – Applying Torque

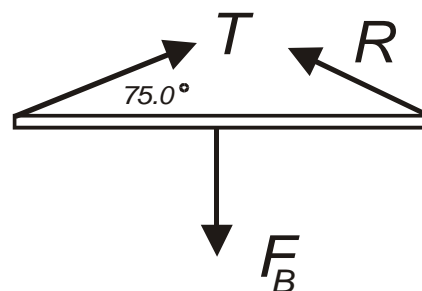
It is now time to go after some problems that are more complicated. You will find these to be a lot of fun. Honest.

- A uniform beam is supported by a stout piece of line as shown. The beam weighs 175 N. The cable makes an angle of 75.0° as shown. Find (a) the tension in the cable and (b) the force exerted on the end of the beam by the wall.



We can solve this problem by summing forces and adding up torques.

First let's draw a FBD:



We have three forces acting on the beam.

The weight of the beam which acts at the center of the beam (its CG), F_B .

The tension in the cable, T .

And the force exerted by the wall on the beam, R . (The wall is pushing the beam up and out.)

(a) Let us first sum the torques. The pivot point is the end of beam where it meets the wall. Therefore R exerts no torque as its lever arm is zero. We only have two torques to deal with and, of course, they add up to zero. Torque one is exerted by the tension in the cable and torque two is caused by the weight of the beam. The force for this torque is applied at the CG, which is at the center of the beam. Only the vertical component of the tension causes its torque so:

$$\tau_{cable} - \tau_B = 0 \quad Tr \sin \theta - F_B \left(\frac{r}{2} \right) = 0$$

$$T = \frac{F_B r}{2 \sin \theta} = \frac{175 \text{ N}}{2 \sin 75.0^\circ} = \boxed{90.6 \text{ N}}$$

(b) Next we can sum up the forces:

$$x \text{ direction: } T \cos \theta - R_x = 0 \quad y \text{ direction: } T \sin \theta - F_B + R_y = 0$$

We can solve the x direction equation for R_x :

$$R_x = T \cos \theta = (90.6 \text{ N}) \cos 75.0^\circ = 23.4 \text{ N}$$

Next we solve for R_y :

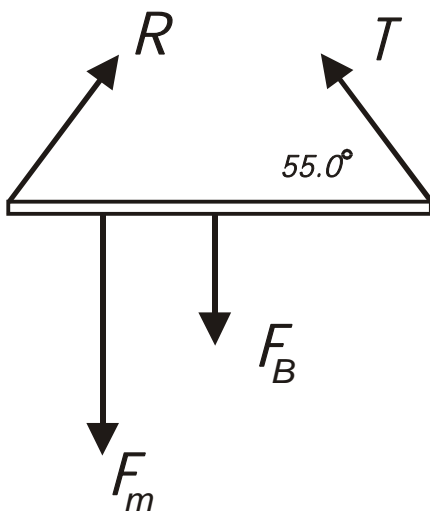
$$R_y = F_B - T \sin \theta = 175 \text{ N} - (90.6 \text{ N}) \sin 75.0^\circ = 87.5 \text{ N}$$

We've found the x and y components for R , so now we can find the magnitude of the vector using the Pythagorean theorem:

$$R = \sqrt{R_y^2 + R_x^2} = \sqrt{(87.5 \text{ N})^2 + (23.4 \text{ N})^2} = \boxed{90.6 \text{ N}}$$

- A beam is supported as shown. The beam is uniform and weighs 300.0 N and is 5.00 m long. A 635 N person stands 1.50 m from the building. (a) What is the tension in the cable and (b) the force exerted on the beam by the building?

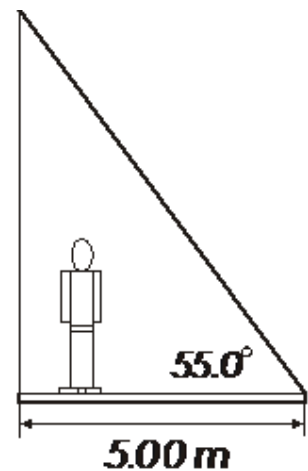
We draw a FBD.



(a) Sum of torques:

$$\tau_{beam} + \tau_{man} - \tau_{cable} = 0$$

$$F_m r_m + F_B r_B - T r_C \sin \theta = 0 \quad T = \frac{F_m r_m + F_B r_B}{(\sin \theta) r_C}$$



$$T = \frac{635 \text{ N}(1.50 \text{ m}) + (300.0 \text{ N})(2.50 \text{ m})}{(\sin 55.0^\circ) 5.00 \text{ m}} = \boxed{416 \text{ N}}$$

(b) We can resolve R and T into components and then sum the forces in the x and y direction. All forces must add up to equal zero.

$$R_x - T \cos \theta = 0 \quad R_y + T \sin \theta - F_B - F_m = 0$$

$$R_x - T \cos \theta = 0 \quad R_x = T \cos \theta = (416 \text{ N}) \cos 55.0^\circ = 238 \text{ N}$$

$$R_y + T \sin \theta - F_B - F_m = 0 \quad R_y = F_B + F_m - T \sin \theta$$

$$R_y = 300.0 \text{ N} + 635 \text{ N} - (416 \text{ N}) \sin \theta = 624 \text{ N}$$

$$R = \sqrt{R_y^2 + R_x^2} = \sqrt{(594 \text{ N})^2 + (238 \text{ N})^2} = \boxed{639 \text{ N}}$$

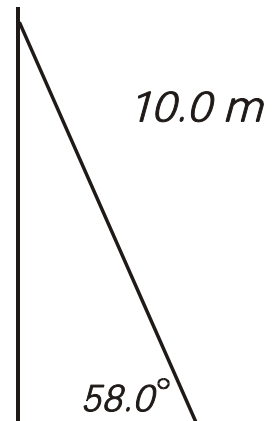
Fabulous Ladder Problems: Ladder problems are very popular. The basic idea is that you have a ladder leaning against a wall (which is usually frictionless). The ladder is held in place by the friction between its base and the deck it rests upon. We're given the situation and then required to figure out various things – the angle the ladder makes with the deck, the friction force, the coefficient of friction, the force exerted on the top of the ladder by the wall, &tc.

Let's go ahead and do a simple problem.

- A uniform 250.0 N ladder that is 10.0 m long rests against a frictionless wall at an angle of 58.0°, the ladder just keeps from slipping. (a) What are the forces acting on the bottom of the ladder? (b) What is the coefficient of friction of the bottom of the ladder with the ground?

Draw a FBD.

The forces acting on the ladder are: the weight of the ladder F_L , the frictional force f , The force the deck pushes up on the ladder with F_1 , and the force exerted by the wall on the top of the ladder F_2 .



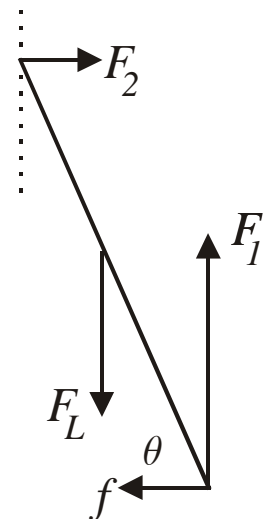
Now we look at the forces acting on ladder - they have to add up to zero.

$$\sum F_y = 0 \quad F_1 - F_L = 0 \quad F_1 = F_L = \boxed{250 \text{ N}}$$

$$\sum F_x = 0 \quad f - F_2 = 0 \quad f = F_2$$

We have to find either F_2 or else f . But we need more info, don't we? You bet we do. Blessed by good fortune as we are, we instantly recognize that we can make use of the torque equilibrium deal.

First we make a drawing showing all the torques acting on the ladder. (Actually we're only looking at the forces that are perpendicular to the lever arm.)



The pivot point is the base of the ladder.

Neither the friction or F_1 cause a torque as their lever arm is zero.

The weight of the ladder causes a CCW torque.

The lever arm from F_2 causes a CW torque.

The torques add up to zero.

$$\sum \tau = 0$$

$$\tau_{ladder} + \tau_{wall} = 0$$

The angle ϕ is, using geometry clearly going to be:

$$\phi = 90^\circ - \theta = 90^\circ - 58^\circ = 32^\circ$$

The torques are: $F_2 \cos \phi d_2 - F_L \cos \theta d_1 = 0$ Solve for F_2 :

$$F_2 = \frac{F_L \cos \theta d_1}{\cos \phi d_2} = \frac{250.0 \text{ N} \cos 58.0^\circ (6.00 \text{ m})}{\cos 32.0^\circ (12.0 \text{ m})} = 78.1 \text{ N}$$

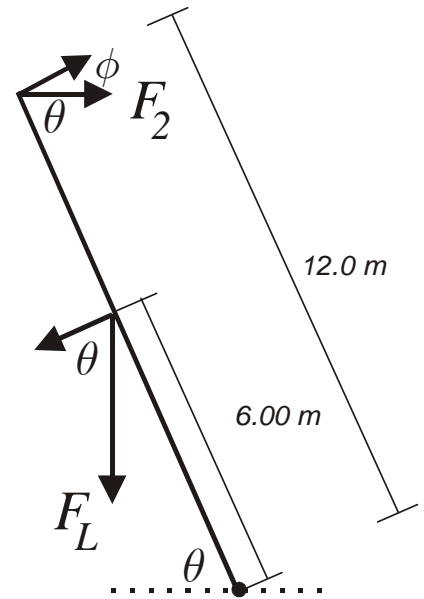
The frictional force (the other force acting at the base of the ladder is therefore:

$$f = \boxed{78.1 \text{ N}}$$

(b) Find the coefficient of friction:

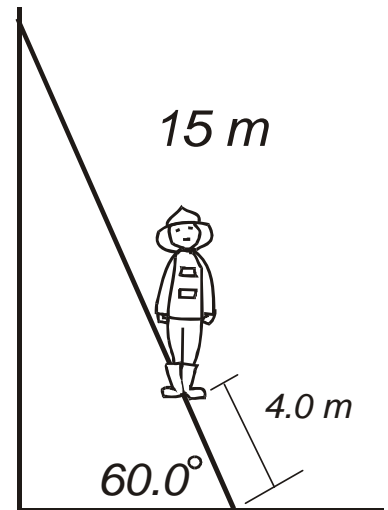
$$f = \mu n \quad \mu = \frac{f}{n} \quad \mu = \frac{78.1 \text{ N}}{250.0 \text{ N}} = \boxed{0.312}$$

Whew! Can we make it worse? You bet.



The longest recorded flight of a domestic chicken is 13 seconds.

- A 15 m, 500.0 N uniform ladder rests against a frictionless wall. It makes 60.0° angle with the horizontal. Find (a) the horizontal and vertical forces on the base of the ladder if an 800.0 N fire fighter is standing 4.0 m from the bottom. If the ladder is on the verge of slipping when the fire fighter is 9.0 m from the bottom of the ladder, (b) what is the coefficient of static friction on the bottom?



$$\sum F_Y = 0$$

$$F_1 - F_L - F_F = 0$$

$$F_1 = F_L + F_F$$

$$F_1 = 500 \text{ N} + 800 \text{ N}$$

$$F_1 = 1300 \text{ N}$$

$$\sum F_X = 0 \quad F_2 - f = 0$$

$$f = F_2$$

Let's look at torque to find F_2 :

$$\sum \tau = 0 \quad \text{Pivot point is at the base of the ladder:}$$

$$\phi = 90^\circ - \theta = 90^\circ - 60^\circ = 30^\circ$$

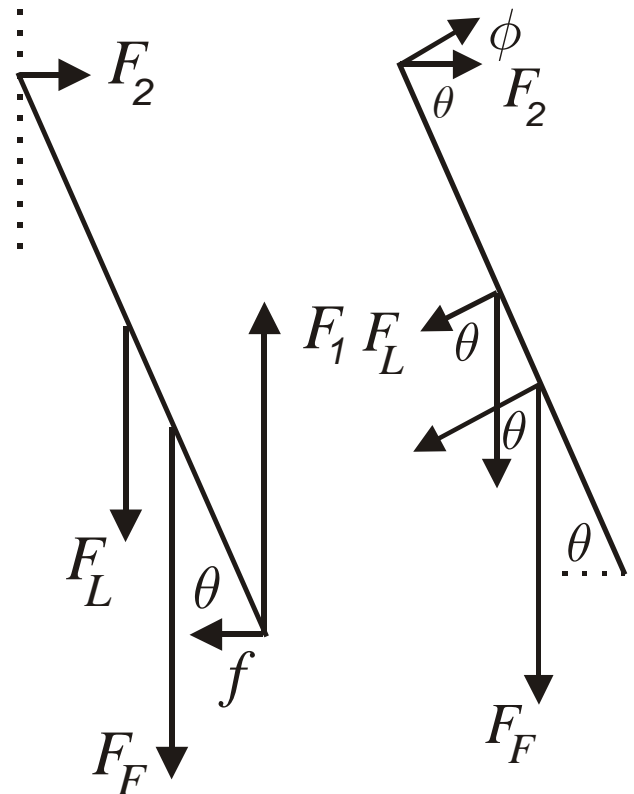
$$\tau_2 - \tau_L - \tau_F = 0$$

$$F_2 \cos \phi r_2 - F_L \cos \theta r_L - F_F r_F = 0$$

$$F_2 = \frac{F_L \cos \theta r_L + F_F r_F}{\cos \phi r_2}$$

$$F_2 = \frac{500.0 \text{ N} \cos 60.0^\circ (7.50 \text{ m}) + 800.0 \text{ N} \cos 60.0^\circ (4.00 \text{ m})}{\cos 30.0^\circ (15.0 \text{ m})}$$

$$F_2 = 270 \text{ N} \quad \text{so} \quad f = 270 \text{ N}$$



So the force up is $F_1 = \boxed{1300\text{ N}}$

The horizontal frictional force is: $f = \boxed{270\text{ N}}$

(b) When the fire man is at 9.0 m (we'll figure this from the bottom of the ladder), then

We can use the same equation as we used to find F_2 since the only thing that has changed is the distance of the firefighter from the bottom of the ladder.

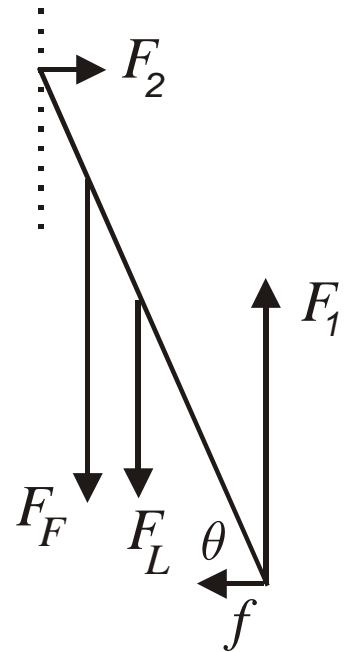
$$F_2 = \frac{F_L \cos \theta r_L + F_F r_F}{\cos \phi r_2}$$

$$F_2 = \frac{500.0\text{ N} \cos 60.0^\circ (7.50\text{ m}) + 800.0\text{ N} \cos 60.0^\circ (9.00\text{ m})}{\cos 30.0^\circ (15.0\text{ m})}$$

$$f = 421\text{ N}$$

We can now find the coefficient of static friction for the bottom of the ladder and the deck.

$$f = \mu_s n \quad \mu_s = \frac{f}{n} = \frac{421\text{ N}}{1300\text{ N}} = \boxed{0.32}$$



All there is to it.

- A superstition of yore involved a young unmarried woman taking a sprig of rosemary and a sprig of thyme, sprinkling them three times with water, and placing each herb in a shoe. She would then put the shoes at the foot of her bed. If she followed this ritual, she was sure to dream of her next true love.
- A U.S. federal law passed in 1994 requires that plastic six-pack ring holders disintegrate after use. This is to prevent birds and marine life from getting tangled in them and strangling.
- About 10 percent of the workforce in Egypt is under 12 years of age. Although laws protecting children are on the books, they are not well enforced, partly because many poverty-stricken parents feel forced to send their children out to help support the family.
- About a hundred years ago, it was the custom of sailors to put a tattoo of a pig on one foot and a rooster on the other to prevent drowning.
- According to “Emily Post’s Etiquette,” a tip at a family restaurant should be 15% of the bill without tax. For a buffet a 10% tip is sufficient, but never leave less than a quarter even if you only have a cup of coffee.
- A in Providence, Rhode Island law makes it illegal to sell a toothbrush on the Sabbath Yet, these same stores are allowed to sell toothpaste and mouthwash on Sundays.

- According to the Recruitment Code of the U.S. Navy, anyone "bearing an obscene and indecent" tattoo will be rejected.
- Almost every weekday morning, free Kleenexes are handed to the commuters in front of Japan's rail and bus stations. The tissues are distributed by workers of the companies whose messages and advertisement are printed on the packages. This is done because most public bathrooms do not have paper towels or toilet paper.
- An old Ethiopian tradition required the jewelry of a bride be removed after her wedding. Its likeness would then be tattooed on her skin.
- An old folk custom for selecting a husband from several suitors involved taking onions and writing each suitor's name individually on each. Then all the onions were put in a cool dark storeroom. The first onion to grow sprouts would determine which man the undecided maiden should marry.
- An old law in Delaware allowed public whipping for 24 crimes--and more than 1,600 people were publicly whipped.
- Bad weather on the way to the wedding is thought to be an omen of an unhappy marriage; some cultures, however, consider rain a good omen. Cloudy skies and wind are believed to cause stormy marriages. Snow, on the other hand, is associated with fertility and wealth.
- Baked goods made on Good Friday were thought to contain many virtues. A cross bun kept from one Good Friday to the next was considered a lucky charm. It was not supposed to grow moldy, and it was used as a charm against shipwreck. "Good Friday bread," when hung over the chimney, was supposed to guarantee that all bread baked after that would be perfect.
- Because of heavy traffic congestion, Julius Caesar banned all wheeled vehicles from Rome during daylight hours.
- Before the enactment of the 1978 law that made it mandatory for dog owners in New York City to clean up after their pets, approximately 40 million pounds of dog excrement were deposited on the streets every year.
- Body language differs from one country to another. For instance, grasping one's ears is a sign of repentance or sincerity in India. A similar gesture in Brazil – holding the lobe of one's ear between the thumb and forefinger – signifies appreciation.
- By photographing the eyes of murder victims, early students of forensics hoped to see a reflection of the murderer lingering in the victim's eyes.
- In Atlanta, Georgia, it is illegal to tie a giraffe to a telephone pole or street lamp.
- In Breton, Alabama, there is a law on the town's books against riding down the street in a motorboat.
- In Britain, a horseshoe was not thought to be lucky traditionally. It was thought to be a guardian against all evil forces, as inhabitants of the spirit world were supposed to flee from the sight of cold iron.
- In Britain, the law was changed in 1789 to make the method of execution hanging. Prior to that, burning was the *modus operandi*. The last female to be executed by burning in England was Christian Bowman. Her crime was making counterfeit coins.
- In Clarendon, Texas, there is a law on the books that lawyers must accept eggs, chickens, or other produce as payment of legal fees.
- In colonial America, tobacco was acceptable legal tender in several Southern colonies, and in Virginia, taxes were paid in tobacco.