Physics 1408/1420

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Hello Fellow Physicists

I am Aman Patel, the Master Tutor for Physics this semester. I have created this resource document to help you review some of the topics you have been introduced to this semester to better prepare for your Final in physics.

Keywords: Static Equilibrium, Stress, Strain

Important Notes

Important Conventions

Static Equilibrium:

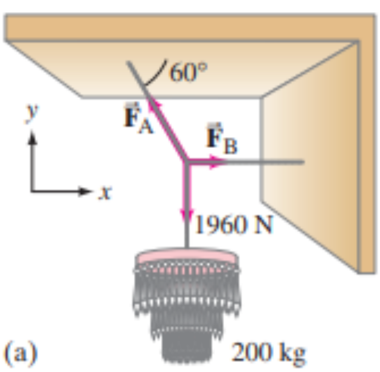
These scenarios are also referred to as statics. Static involves the analysis of all the forces in play within a system that are in equilibrium. A system is in equilibrium when all the forces in a system are balanced. Hence, the sum of forces in the three axes must be as follows:

$$\Sigma F_x = 0, \qquad \Sigma F_y = 0, \qquad \Sigma F_z = 0.$$

The most important tool at your disposal is a free body diagram/ dot diagram. Let look at an example.

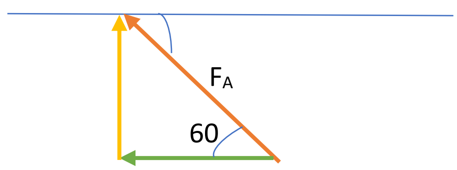
Example

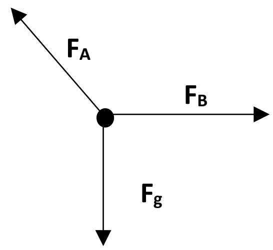
Calculate the tensions F_A and F_B in the two cords that are connected to the vertical cord supporting the 200 kg chandelier.



(a)

Solution





The best strategy to approach statics problems is to make a dot diagram and then split the page into two for the analyzing the x and y axes.

$\sum F_Y = 0$

$F_A \sin 60° - F_g = 0$

$F_A \sin 60° = F_g$

$F_A = mg / \sin 60°$

$= (200)(9.8) / \sin 60°$

$= 2260$ N

$\sum F_X = 0$

$-F_A \cos 60° + F_B = 0$

$F_B = F_A \cos 60°$

$= 2260 \cos 60°$

$= 1130$ N

This approach is important because statics will involve many different forces and many of them may act at an angle. Splitting your outlook in two different axes will help simplify your analysis significantly. I highly recommend practicing this approach when dealing with statics.

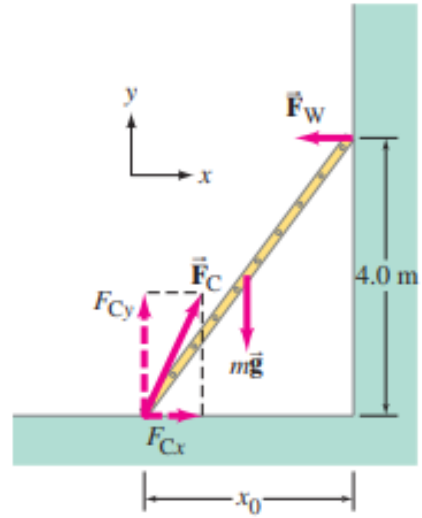
Another constant in a static equilibrium system is the sum of the torques in the system.

$$\Sigma\tau = 0.$$

Let's look at an example using torque

Example:

A 5 m long ladder leans against a wall at a point 4 m above the floor. The ladder has a mass of 12 kg. Assuming the wall is frictionless, but the floor is not, determine the forces exerted on the ladder by the floor and by the wall.



Solution

Y-Axis:

$\sum F_Y = 0$

$F_{Cy} - F_g = 0$

$F_{Cy} = F_g$

$= m\,g$

$= 12 \,.\, 9.8$

$= 118$ N

X-Axis:

$\sum F_X = 0$

$F_{Cx} - F_w = 0$

$F_{Cx} = F_w$

Since both forces are unknown, we will move onto the final torque to see if we can acquire one of the forces

$5^2 = 4^2 + x^2$

$x = 3$

$\sum \tau = 0$

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

$F_w\, y - F_g\,(x/2) = 0$

$F_w = mg(x/2)/y$

$F_w = (12)(9.8)(3/2) / 4$

$F_w = 44 \text{ N} = F_{Cx}$

$F_C = ((F_{Cx})^2 + (F_{Cy})^2)^{1/2} = ((44)^2 + (118)^2)^{1/2} = 126 \text{ N}$

Elasticity: Stress and Strain

When it comes to elastic objects, Hooke's law applies when considering the force they exert or force that must be exerted on them to cause a displacement. Hooke's law states:

$$F = k\,(l - l_0)$$

But as you may know, there is a limit that an object can be stretched or compressed to before the object breaks. The maximum force that can be applied before breaking object is the called the ultimate strength.

All objects have their own limits. Object can experience stress and strain.

$$\text{stress} = \frac{\text{force}}{\text{area}} = \frac{F}{A}, \qquad \text{strain} = \frac{\text{change in length}}{\text{original length}} = \frac{\Delta \ell}{\ell_0},$$

Based on the type of object, they are subject to three different types strain and stress, they all dictate different properties about the material. Young's Modulus (E), Shear Modulus(G) and Bulk Modulus (B).

$$\Delta \ell = \frac{1}{E}\frac{F}{A}\ell_0, \qquad \Delta \ell = \frac{1}{G}\frac{F}{A}\ell_0 \qquad \frac{\Delta V}{V_0} = -\frac{1}{B}\Delta P$$

Example

A 1.6 m long steel piano wire has a diameter of 0.2 cm. How great is the tension in the wire if it stretches 0.25 cm when tightened?

Solution

$F = E\,A\,(l - l_0)/l_0$

$= (2 \times 10^{11})(0.0025 / 1.6)(\pi\,(0.0001)^2)$

$= 980$ N

Statics is a highly important topic. Every architect and engineer that designs man-made structures, from your house to the Empire State building, must consider numerous different variables when they make these structure. This involves dimensions and the materials used. The next time you walk into the BSB, take a moment to consider the amazing structure's design and system of forces in play that affected its design.

All images are from Physics: Principles with Applications (7th Edition) by Douglas C. Giancoli