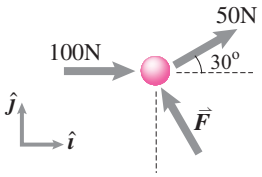
5.1 Static equilibrium of a particle

Preparatory Problems

5.1.1 What is a particle?

5.1.2 What are the equations of equilibrium for a particle (also called "*equilibrium conditions*", "*force balance*", or "*linear momentum balance for statics*"?

5.1.3 The particle shown in the figure is in static equilibrium. Find the unknown force $\vec{F}$.



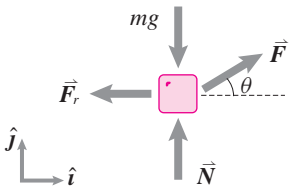
Problem 5.1.3

5.1.4 Four forces act on a block as shown in the figure and hold it in static equilibrium. Assume that the magnitude of force $\vec{F}$ is known and it is F.

a) Write the scalar equations of equilibrium in the x and y directions.

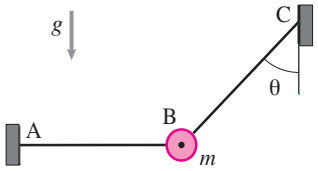
b) Solve for $\vec{N}$ and $\vec{F}_r$ in terms of F, mg, and θ.

c) What is $\vec{F}_r$ when $\theta = 90°$?



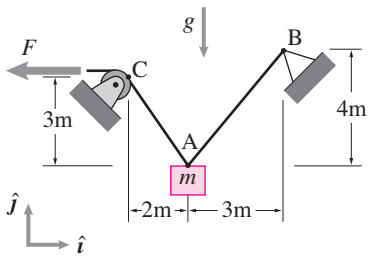
Problem 5.1.4

5.1.5 A particle of mass $m = 2$ kg hangs from strings AB and AC as shown. AB is horizontal and $\theta = 45^\circ$. Find the tension in the two strings.



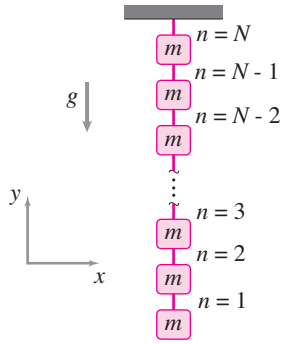
Problem 5.1.5

5.1.6 What force should be applied to the end of the string over the pulley at C so that the mass at A is at rest in the configuration shown?



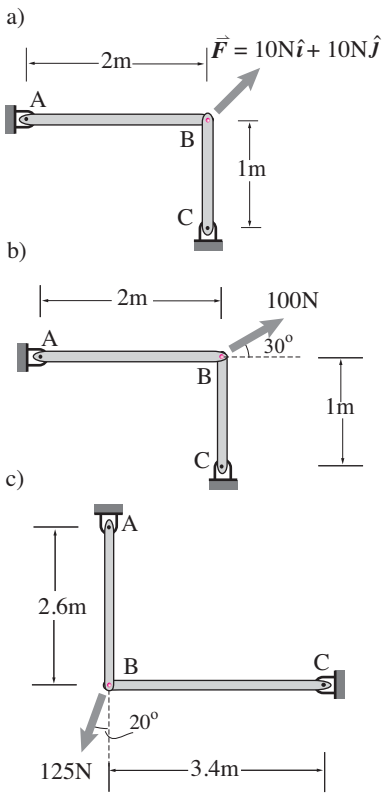
Problem 5.1.6

5.1.7 N small blocks each of mass m hang vertically as shown, connected by N inextensible strings. Find the tension T_n in string n. *



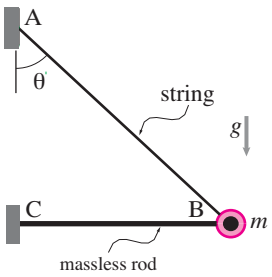
Problem 5.1.7

5.1.8 For each situation below, assume static equilibrium under the applied force and find the tensions in the two rods.



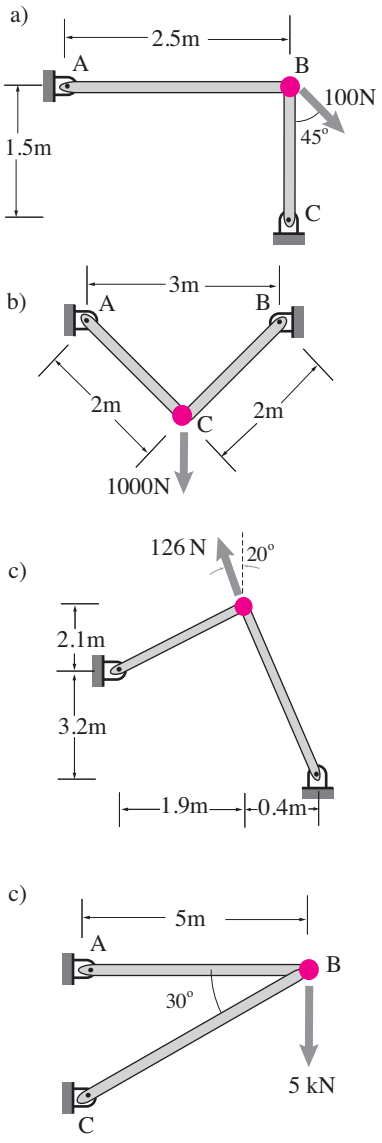
Problem 5.1.8

5.1.9 A particle of mass m = 5 kg at the end of a horizontal massless rod CB of length 1.2 m is held in place with the help of a string AB that makes an angle $\theta = 45^\circ$ with the vertical in the equilibrium position. Find the tension in the bar CB (it is ok to have negative tension).



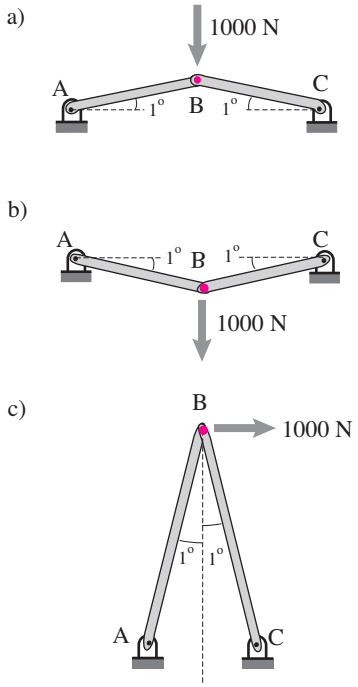
Problem 5.1.9

5.1.10 For each structure shown below, find the tension in each rod. (Note the tension can be less than zero.)



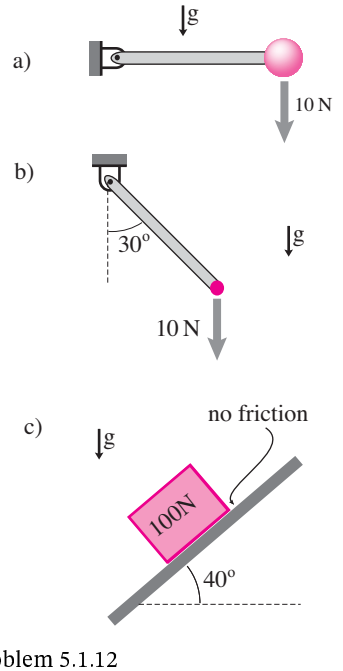
Problem 5.1.10

5.1.11 In the following structures, a pin connects two thin bars that are very nearly either horizontal or vertical. Find the tensions in each rod under the applied loads. (Note the tension is less than zero for some of the rods.)



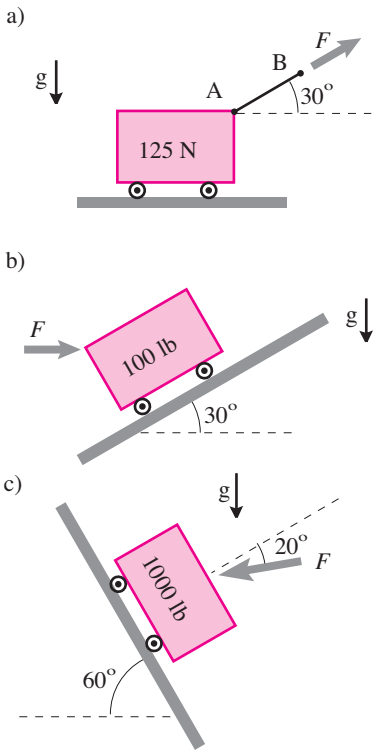
Problem 5.1.11

5.1.12 For each situation shown below, equilibrium is not possible. Write the vector equation for force balance and show that it has no solutions (*i.e.*, leads to an equation like $7 = 0$).



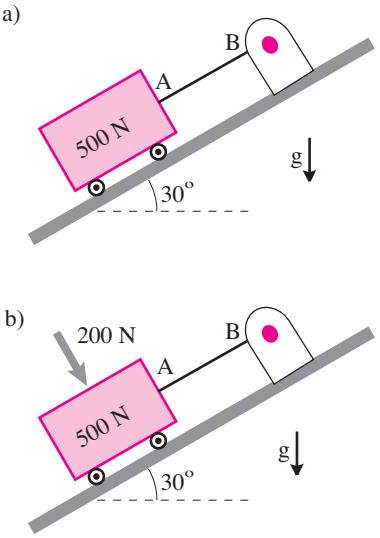
Problem 5.1.12

5.1.13 Assume no sliding friction ($\mu = 0$). Assume equilibrium. Find all reactions, tensions, and forces. *



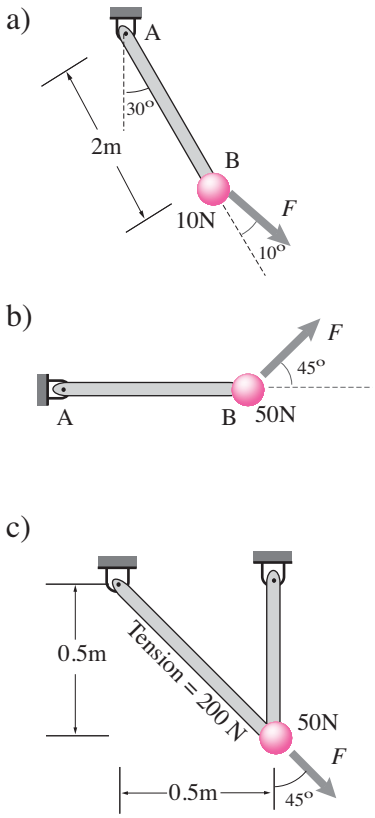
Problem 5.1.13

5.1.14 In each of the two cases given below, find the tension in the string AB assuming the block to be at rest and the ramp to be frictionless.



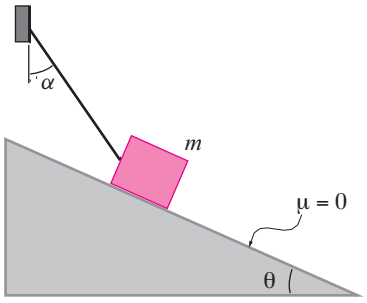
Problem 5.1.14

5.1.15 Find the unknown forces and tensions in each structure shown below.



Problem 5.1.15

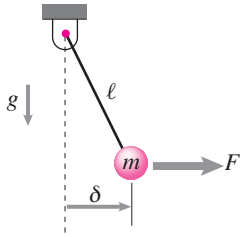
5.1.16 A block of mass $m = 5$ kg rests on a frictionless inclined plane as shown in the figure. Let $\theta = \alpha = 30^\circ$. Find the tension in the string.



Problem 5.1.16

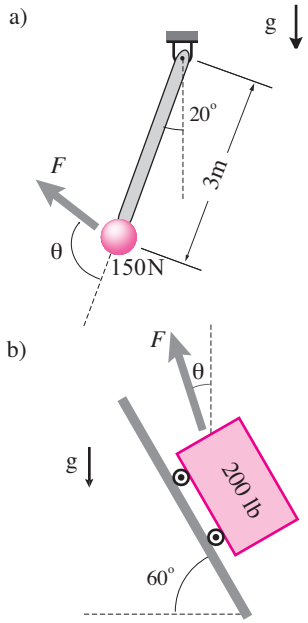
More-Involved Problems

5.1.17 For small δ what is the relation between F and δ (and g and ℓ) for a static pendulum?



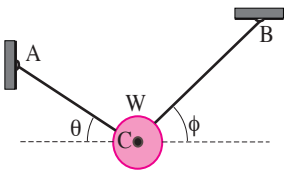
Problem 5.1.17

5.1.18 In the situations shown in the figures, find the value of θ that minimizes F. What is the corresponding value of F in each case?



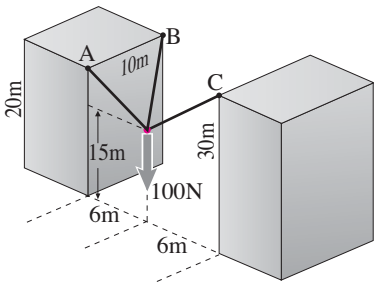
Problem 5.1.18

5.1.19 An object of weight $W = 10$ N is held in equilibrium in the vertical plane by two strings AC and BC. Let $\theta = 30^\circ$ and $0 \le \phi \le 90^\circ$. Find and plot the tension in the two strings against ϕ and comment on the variation in the tensions.



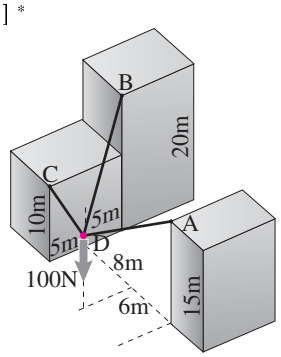
Problem 5.1.19

5.1.20 Find the tensions in the three strings shown in the figure.



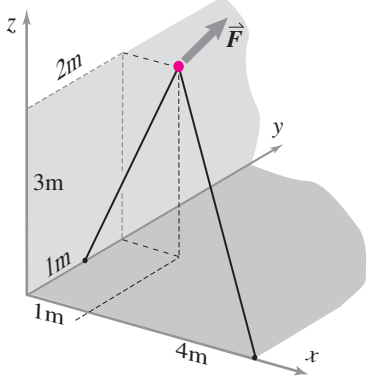
Problem 5.1.20

5.1.21 Find the tensions in the three strings shown in the figure. String CD is horizontal and the force at D is 100 N straight down. [Hint: this problem has a trick to it.] *



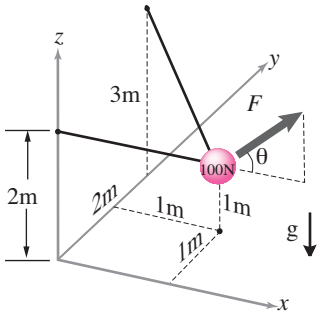
Problem 5.1.21

5.1.22 Show that the particle acted upon by the given force $\vec{F} = (3\hat{\imath} + 4\hat{\jmath} + 5\hat{k})$ N, and held by the two bars as shown in the figure cannot be in equilibrium.

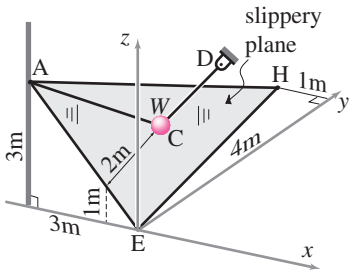


Problem 5.1.22

5.1.23 In the figure shown, the force $\vec{F}$, in the x-z plane, acts on the particle (weighing 100 N). Find F as a function of θ for equilibrium of the particle. Find the value of θ for which the required force is smallest.

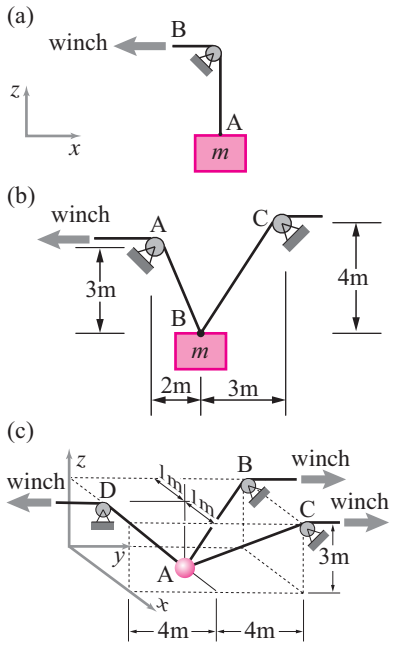


Problem 5.1.23



Problem 5.1.25

5.1.24 For the three cases (a), (b), and (c), below, find the tension in the string AB. In all cases the strings hold up the mass $m = 3$ kg. You may assume the local gravitational constant is $g = 10\ \text{m/s}^2$. In all cases the winches are pulling in the string so that the velocity of the mass is a constant 4 m/s upwards (in the $\hat{\boldsymbol{k}}$ direction). [Note that in problems (b) and (c), in order to pull the mass up at constant rate the winches must pull in the strings at an unsteady speed.] *



Problem 5.1.24

5.1.25 A block of weight W, held by two strings AC and DC, rests on a slippery plane AEH. String CD is parallel to EH. Find the tensions in the two strings and the reaction of the plane. You may approximate AC to lie in the plane AEH.