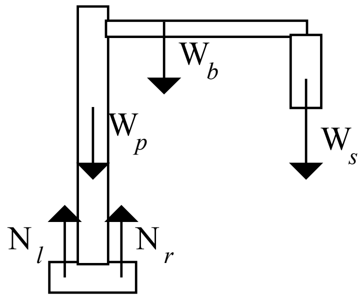
Chapter 12 Problem 24 †



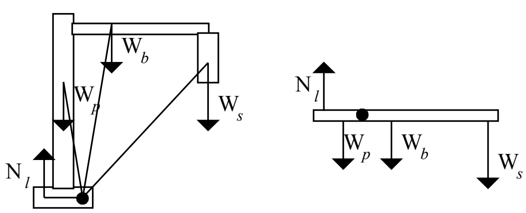
Given
Figure 12.16

Solution
Find the force exerted on the left hand bolt.

The free body diagram of the traffic signal is given above. To satisfy static equilibrium, the sum of forces in the x and y directions must be zero. In the y direction Newton's 2_{nd} law gives the following formula.

$$\Sigma F_y = N_l + N_r - W_p - W_b - W_s = 0$$

There are no forces in the x direction and, therefore, Newton's 2_{nd} law doesn't give any additional information.
To write out the sum of torques, a pivot point must be chosen. Let us choose the location of the force, N_r. This will leave us with an equation with only one unknown, N_l.
Since the torque is $r \cdot F \sin\theta$, then the component of each force arm perpendicular to its respective force is $r \cdot \sin\theta$ and this results in the force diagram given below.



The torque equation is then

$$\Sigma\tau = -(r_l \sin\theta_l)N_l + (r_p \sin\theta_p)W_p - (r_b \sin\theta_b)W_b - (r_s \sin\theta_s)W_s = 0$$

Solving for N_l gives

$$N_l = \frac{(r_p \sin\theta_p)W_p - (r_b \sin\theta_b)W_b - (r_s \sin\theta_s)W_s}{(r_l \sin\theta_l)}$$

The weight of each portion is mass times the acceleration of gravity. Factoring out the acceleration of gravity gives

$$N_l = \frac{g\left((r_p \sin\theta_p)m_p - (r_b \sin\theta_b)m_b - (r_s \sin\theta_s)m_s\right)}{(r_l \sin\theta_l)}$$

†Problem from Essential University Physics, Wolfson

Substituting in the values for the masses and the horizontal component of the force arm gives

$$N_l = \frac{(9.80\ m/s^2)\left((0.38\ m)(321\ kg) - (3.22\ m)(175\ kg) - (7.84\ m)(64.7\ kg)\right)}{(0.76\ m)}$$

$$N_l = -12,200\ N = -12.2\ kN$$

The negative sign indicates that the direction of the force, N_l is downward. (Opposite direction from how it is drawn on the free-body diagram)