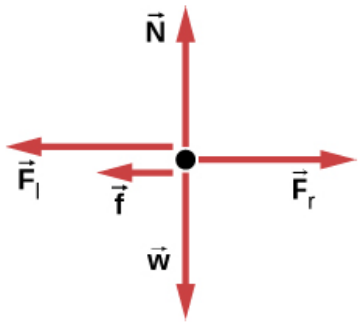
Chapter 5 Problem 32 [†]



Given
$\vec{F}_r = 90.0\hat{i}\ N$
$\vec{F}_l = -75.0\hat{i}\ N$
$\vec{F}_f = -12.0\hat{i}\ N$
$m = 23.0\ kg$

Solution
What is the system of interest?

In this problem the system of interest is the wagon and the child in it. The free-body (force) diagram illustrates all of the forces acting on this system. Notice the two children pushing on the wagon are not part of the system. They are external to the system, but acting on it.

b) Calculate the acceleration.

Using Newton's 2nd law gives

$$\Sigma\vec{F} = m\vec{a}$$

Substituting in all of the forces gives

$$\vec{F}_f + \vec{F}_l + \vec{F}_r + \vec{W} + \vec{N} = m\vec{a} \qquad Eq.(1)$$

Notice that the summation symbol means to add all the forces. The positive and negative signs will show up as we substitute in the values for each of the vectors. Now the weight is

$$\vec{W} = -mg\hat{j}$$

and the normal force is

$$\vec{N} = N\hat{j}$$

Substituting these values into equation (1) and assume the acceleration is only in the horizontal direction gives

$$(-12.0\hat{i}\ N) + (-75.0\hat{i}\ N) + (90.0\hat{i}\ N) + (-mg\hat{j}) + (N\hat{j}) = ma\hat{i}$$

Simplifying the equation gives

$$(-12.0 - 75.0 + 90.0)\hat{i}\ N + (-mg + N)\hat{j} = ma\hat{i}$$

[†]Problem from University Physics by Ling, Sanny and Moebs (OpenStax)

In the vertical direction (y-direction) we have

$$-mg + N = 0$$

Therefore, the normal force is equal to the weight of the wagon and child in the wagon. The normal force is then

$$N = mg = (23.0\ kg)(9.80\ m/s^2) = 225\ N$$

In the horizontal direction (x-direction) we have

$$(-12.0 - 75.0 + 90.0)\ N = (23.0\ kg)a$$

Solving for acceleration gives

$$a = \frac{(-12.0 - 75.0 + 90.0)\ N}{23.0\ kg} = \frac{3.0\ N}{23.0\ kg}$$

$$a = 0.13\ m/s^2$$

c) What is the acceleration if the frictional force is 15.0 N.

Using this new value for friction gives

$$a = \frac{(-15.0 - 75.0 + 90.0)\ N}{23.0\ kg} = \frac{0\ N}{23.0\ kg}$$

$$a = 0\ m/s^2$$