Force and Force Balance in One-Dimensional Systems

What is a force?

A force describes the interaction between objects, which can be distinguished as pushing and pulling forces. For example, a small ball with mass will be attracted by the earth, and this attraction is a kind of force called gravity. Intuitively, when the state of motion of an object is changed, whether from rest to motion, or from motion to rest, or from an accelerating state to a non-accelerating state, the action of force is indispensable.

How to represent the force of an object?

In physics, we often use force diagrams to represent the force of an object. For example, suppose there is a block that is subjected to a pulling force to the left. We can represent the force on this object in the form of an arrow, where the direction of the arrow is to the left, the length of the arrow is the magnitude of the force, and the base of the arrow is the point of application of the force.

One-Dimensional Force Balance

Net Force

When an object is affected by multiple forces, we usually use the sum of the forces to represent the force on the object, and these summed forces are called net force. In a one-dimensional system, we can simply calculate the net force by adding and subtracting real numbers. For example, if an object is subjected to two forces, one downward force of 5 units and one upward force of 3 units, then the net force on this object is a downward force of 2 units.

Force balance in a one-dimensional system

When the **net force on an object in the system is zero**, we call it force balance (translation equilibrium), which usually presents a state of **rest** or **constant velocity** in physics.

Sample Problem #1

Now there is an object, which is subjected to two forces to the right, respectively 6 and 3 units, and they act on the left and right sides of the object, respectively. What is the net force of this object? If you want to add a force to keep the object in a state of translational rest, what should be the net force on the object, and how much should the added force be?

Sol.

Sample Problem #2

An object on a horizontal plane is subjected to two forces, a pushing force to the right $F_1 = 10\mathrm{N}$ and a pulling force to the left $F_2 = 5\mathrm{N}$. Please draw the force diagram of the object and answer the following questions: (a) What is the total force and direction of force on this object? (b) If you want to add a pushing force to keep the object moving at a constant velocity, how much should this pushing force be? Please draw this pushing force on the diagram.

Sol.

Exercises

Exercise #1

Now there is a physicist who wants to use electromagnetic interaction force to measure the charge of a charged particle. The experimental device mainly uses the gravitational fall of the particle and applies an upward electromagnetic force to fix the particle in the air, so that the charge of the particle can be obtained. If it is known that the gravity on the particle is w, and the electromagnetic force on the particle can be described as qE, where q is the charge and E is the electromagnetic field strength, if the experiment observes that the particle just stops when the electromagnetic field strength is E_0, then how much is the charge carried by the particle?

Sol.

Exercise #2

An object is interacted by a downward gravitation force $F = 15\ \mathrm{N}$ and a vetical external force F_{rope} by a rope, answer the following questions: (a) If the rope is hanging still, what is the force acted on the object by the rope? (b) If you want to add a new vertical external force to make the rope tension $F_{\mathrm{rope}} = 20\ \mathrm{N}$, how much should this external force be? (The object can be in a non-hanging state)

Sol.

Solutions

Sample Problem #1

Now there is an object, which is subjected to two forces to the right, respectively 6 and 3 units, and they act on the left and right sides of the object, respectively. What is the net force of this object? If you want to add a force to keep the object in a state of translational rest, what should be the net force on the object, and how much should the added force be?

The net force on an object is the vector sum of all the forces acting on it. In this case, there are two forces acting on the object to the right, 6 units and 3 units. So, the net force on the object is the sum of these two forces.

$$F_{net} = F_1 + F_2 = 6 + 3 = 9 \text{ units to the right} \tag{1}$$

If we want to keep the object in a state of translational rest, the net force on the object should be zero. This means we need to apply an additional force to the object that is equal in magnitude but opposite in direction to the current net force.

$$F_{added} = -F_{net} = -9 = -9 \text{ units to the left} \tag{2}$$

Sample Problem #2

An object on a horizontal plane is subjected to two forces, a pushing force to the right $F_1 = 10\text{N}$ and a pulling force to the left $F_2 = 5\text{N}$. Please draw the force diagram of the object and answer the following questions: (a) What is the total force and direction of force on this object? (b) If you want to add a pushing force to keep the object moving at a constant velocity, how much should this pushing force be? Please draw this pushing force on the diagram.

(a) The total force on the object is the vector sum of all the forces acting on it. In this case, there are two forces acting on the object, $F_1 = 10\text{N}$ to the right and $F_2 = 5\text{N}$ to the left. So, the net force on the object is the difference of these two forces.

$$F_{net} = F_1 - F_2 = 10\text{N} - 5\text{N} = 5\text{N} \text{ to the right} \tag{3}$$

(b) If we want to keep the object moving at a constant velocity, the net force on the object should be zero. This means we need to apply an additional force to the object that is equal in magnitude but opposite in direction to the current net force.

$$F_{added} = -F_{net} = -5\text{N} = -5\text{N} \text{ to the left} \tag{4}$$

Exercise #1

Now there is a physicist who wants to use electromagnetic interaction force to measure the charge of a charged particle. The experimental device mainly uses the gravitational fall of the particle and applies an upward electromagnetic force to fix the particle in the air, so that the charge of the particle can be obtained. If it is known that the gravity on the particle is w, and the electromagnetic force on the particle can be described as qE, where q is the charge and E is the electromagnetic field strength, if the experiment observes that the particle just stops when the electromagnetic field strength is E_0, then how much is the charge carried by the particle?

When the particle just stops, the gravitational force on the particle is balanced by the electromagnetic force. Therefore, we have $w = qE_0$. So, the charge carried by the particle is:

$$q = \frac{w}{E_0} \tag{5}$$

Exercise #2

An object is interacted by a downward gravitation force $F = 15\ \mathrm{N}$ and a vetical external force F_{rope} by a rope, answer the following questions: (a) If the rope is hanging still, what is the force acted on the object by the rope? (b) If you want to add a new vertical external force to make the rope tension $F_{\mathrm{rope}} = 20\ \mathrm{N}$, how much should this external force be? (The object can be in a non-hanging state)

(a) When the object is hanging still, the force acted on the object by the rope is equal to the weight of the object. Therefore, the force is:

$$F_{\mathrm{rope}} = F = 15\ \mathrm{N} \tag{6}$$

(b) If you want to make the rope tension $F_{\mathrm{rope}} = 20\ \mathrm{N}$, there are two scenarios depending on the direction of the external force:

1. If the external force is applied upward (in the same direction as the rope force): The external force should be the difference between the desired tension and the weight of the object. Therefore, the external force should be:

$$F_{\mathrm{external}} = F_{\mathrm{rope}} - F = 20\ \mathrm{N} - 15\ \mathrm{N} = 5\ \mathrm{N}(\mathrm{upward}) \tag{7}$$

2. If the external force is applied downward (in the opposite direction to the rope force): The external force should be the sum of the desired tension and the weight of the object. Therefore, the external force should be:

$$F_{\mathrm{external}} = F_{\mathrm{rope}} + F = 20\ \mathrm{N} + 15\ \mathrm{N} = 35\ \mathrm{N}(\mathrm{downward}) \tag{8}$$