Common Force Part I

Gravity

Gravity is a concept of force, it describes the interaction between two objects with mass. For an object on Earth, we can consider gravity as the gravitational force that the Earth exerts on the object. Through experiments, we know that near the surface of the Earth, an object under the influence of gravity will accelerate, and its acceleration value is approximately $g = 9.8\ \mathrm{m/s^2}$. According to Newton's second law of motion, we can deduce that the gravity an object experiences near the surface of the Earth is $F = mg$, where m is the mass of the object.

Weight

The concept of weight is basically similar to gravity, but accurately speaking, weight refers to the reading on the scale, that is, the force received by the scale. When an object is not affected by other external forces, its weight is equal to the gravity it experiences. We can record their relationship as follows:

$$W = mg \tag{1}$$

However, when an object is affected by other external forces, its weight will change accordingly. For example,suppose an object has a mass of m and is affected by gravity and an upward external force F_{up}, the force received by the scale will become $mg - F_{\mathrm{up}}$, so the weight will also become $W = mg - F_{\mathrm{up}}$.

Sample Problem #1

It is known that the weight of an object measured on the Alpha planet is 6 times that of the earth. If an object of weight m is launched upward with the same initial velocity v_0, what is the difference in the maximum height measured by the object on the earth and the Alpha planet?

Sol.

Sample Problem #2

Suppose there is an object of mass m on the earth, moving downward with an acceleration of $0.3g$, (a) what is the net force F_{net} on the object? (b) What is the sum of the non-gravitational forces on the object?
If the object moves upward with an acceleration of $0.5g$, (c) what is the net force F_{net} on the object? (d) What is the sum of the non-gravitational forces on the object?

Sol.

Normal Force

Normal force is a concept of force, it describes the force that a surface exerts on an object with which it is in contact. Namely, it is always perpendicular to the surface.

For an object resting on a flat surface, the normal force counteracts the weight of the object. The normal force can be calculated as $N = mg$, where m is the mass of the object and g is the acceleration due to gravity.

Sample Problem #3

There is a block of mass m placed on a horizontal table, (a) what is the force exerted by the block on the horizontal table? (b) What is the normal force exerted by the horizontal table on the block? (c) If the table and the block move together at a constant speed on the horizontal table, what is the net force on the block? What is the normal force on the block? (d) If the table and the block move together on the horizontal table with a downward acceleration of $0.3g$, what is the net force on the block? What is the normal force on the block?

Sol.

Tension

Tension is a concept of force, it describes the pulling force transmitted by a string, cable, chain, or similar one-dimensional continuous object, or by each end of a rod, truss member, or similar three-dimensional object. Tension might also be described as the action-reaction pair of forces acting at each end of the said elements. Tension could depend on the length and elasticity of the object, and the force applied. The unit of tension is the same as the unit of force, that is, Newton (N).

Light String

In the context of a light string, the term **light** refers to the string being **massless or of negligible mass**. When a force is applied to such a string, it can be assumed that the tension throughout the string is uniform. This is because a light string does not have its own weight to affect the tension. Therefore, the tension at one end of the string is equal to the tension at the other end.

Sample Problem #4

There is a block with a mass of 0.5kg. Now it is hung from the ceiling with a light rope. The mass of the rope can be ignored. If the block is at rest, what is the tension of the rope?

Sol.

Sample Problem #5

There are two blocks with weights of 0.5kg and 1kg respectively. Now they are strung on the ceiling with a light rope. The order is that the heavier block is on the lighter block, and the mass of the rope can be ignored. If the blocks are at rest, answer the following questions: (a) What is the tension of the rope connecting the ceiling and the blocks? (b) What is the tension of the rope between the two blocks?

Sol.

Exercises

Exercise #1 [Halliday 5.86]

Sol.

Exercise #2 [Halliday 5.13]

Sol.

Exercise #3 [Halliday 5.14]

Sol.

Exercise #4 [Halliday 5.15]

Sol.

Exercise #6 [Halliday 5.93]

Sol.

Solutions

Sample Problem #1

What is the difference in the maximum height measured by the object on the earth and the Alpha planet?

The maximum height reached by an object launched upward is given by the formula:

$$h = \frac{v_0^2}{2g} \tag{1}$$

On Earth, the maximum height is:

$$h_{\text{earth}} = \frac{v_0^2}{2g} \tag{2}$$

On the Alpha planet, where the gravitational acceleration is 6 times that of Earth, the maximum height is:

$$h_{\text{alpha}} = \frac{v_0^2}{2 \cdot 6g} = \frac{v_0^2}{12g} \tag{3}$$

The difference in the maximum height is:

$$\Delta h = h_{\text{earth}} - h_{\text{alpha}} = \frac{v_0^2}{2g} - \frac{v_0^2}{12g} = \frac{5v_0^2}{12g} \tag{4}$$

Sample Problem #2

(a) What is the net force F_{net} on the object?

The net force is given by Newton's second law:

$$F_{\text{net}} = ma = m \cdot 0.3g = 0.3mg \tag{5}$$

(b) What is the sum of the non-gravitational forces on the object?

The gravitational force is mg. The net force is the sum of all forces, so the non-gravitational force $F_{\text{non-grav}}$ is:

$$F_{\text{non-grav}} = F_{\text{net}} + mg = 0.3mg + mg = 1.3mg \tag{6}$$

(c) What is the net force F_{net} on the object if it moves upward with an acceleration of $0.5g$?

The net force is:

$$F_{\text{net}} = ma = m \cdot (-0.5g) = -0.5mg \tag{7}$$

(d) What is the sum of the non-gravitational forces on the object?

The non-gravitational force is:

$$F_{\text{non-grav}} = F_{\text{net}} - mg = -0.5mg + mg = 0.5mg \tag{8}$$

Sample Problem #3

(a) What is the force exerted by the block on the horizontal table?

The force exerted by the block on the horizontal table is its weight, which is given by:

$$F_{\text{block}} = -mg \tag{9}$$

(b) What is the normal force exerted by the horizontal table on the block?

The normal force exerted by the table on the block is equal in magnitude and opposite in direction to the force exerted by the block on the table, assuming no other vertical forces are acting. Therefore:

$$F_{\text{normal}} = mg \tag{10}$$

(c) If the table and the block move together at a constant speed on the horizontal table, what is the net force on the block? What is the normal force on the block?

If the block and table move together at a constant speed, the net force on the block is zero because there is no acceleration. The normal force remains the same as when the block is stationary:

$$F_{\text{net}} = 0 \Rightarrow F_{\text{normal}} = mg \tag{11}$$

(d) If the table and the block move together on the horizontal table with a downward acceleration of $0.3g$, what is the net force on the block? What is the normal force on the block?

If the block and table move downward with an acceleration of $0.3g$, the net force on the block is:

$$F_{\text{net}} = ma = m \cdot (-0.3g) = -0.3mg \tag{12}$$

The normal force is the difference between the gravitational force and the net force due to the downward acceleration:

$$F_{\text{normal}} = mg - 0.3mg = 0.7mg \tag{13}$$

Sample Problem #4

What is the tension of the rope if the block is at rest?

When the block is at rest, the tension in the rope is equal to the weight of the block. The weight of the block is given by:

$$F_{\text{weight}} = mg \tag{14}$$

Given that the mass of the block is 0.5 kg and the acceleration due to gravity is approximately 9.8 m/s², the tension in the rope is:

$$T = 0.5\,\text{kg} \times 9.8\,\text{m/s}^2 = 4.9\,\text{N} \tag{15}$$

Sample Problem #5

(a) What is the tension of the rope connecting the ceiling and the blocks?

The tension in the rope connecting the ceiling and the blocks must support the weight of both blocks. The total weight is:

$$T_{\text{ceiling}} = (0.5\,\text{kg} + 1\,\text{kg}) \times 9.8\,\text{m/s}^2 = 1.5\,\text{kg} \times 9.8\,\text{m/s}^2 = 14.7\,\text{N} \tag{16}$$

(b) What is the tension of the rope between the two blocks?

The tension in the rope between the two blocks must support the weight of the lighter block only. Therefore, the tension is:

$$T_{\text{between}} = 0.5\,\text{kg} \times 9.8\,\text{m/s}^2 = 4.9\,\text{N} \tag{17}$$

Exercise #1 [halliday 5.86]

(a) 7.4×10^2 N ; (b) 2.8×10^2 N ; (c) 0 N ; (d) 75 kg

Exercise #2 [halliday 5.13]

(a) 4.0 kg ; (b) 1.0 kg ; (c) 4.0 kg ; (d) 1.0 kg

Exercise #3 [halliday 5.14]

(a) 2 N ; (b) downward

Exercise #4 [halliday 5.15]

(a) 108 N ; (b) 108 N ; (c) 108 N

Exercise #5 [halliday 5.93]

(a) 44 N ; (b) 78 N ; (c) 54 N ; (d) 152 N