

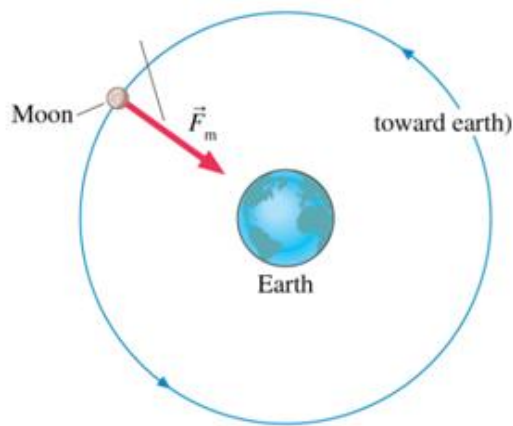
<h1>CHAPTER 2</h1>	<h2>FORCE AND MOTION</h2>
<h3>CHAPTER'S OBJECTIVES</h3>	<p>In chapter 1, we understood that the Greek philosopher Aristotle was the first who studied motion and asked questions of "what causes motion?" His views were based on observation and rational thinking, but not on measurement (experimentation). Yet, he had it all wrong when he concluded that a heavy object falls faster than light object and a force is necessary to keep an object moving along a horizontal line.</p>
<ul style="list-style-type: none"><li>• To define a force</li><li>• To understand the relation between force and motion</li><li>• To introduce the balanced and unbalanced forces</li><li>• To introduce the concept inertia</li><li>• To introduce Newton's three laws of motion</li><li>• To discuss the free fall motion</li><li>• To discuss and introduce the terminal speed</li><li>• To introduce Newton's universal law of gravity</li></ul>	<p>This chapter is all about Galileo's, and Newton's modern views of motions and forces (dynamics), which are held true since the 16<sup>th</sup> century.</p>

## 2.1 Force

From everyday experience, a **force**  $\vec{F}$  is a push or pull on an object to change its position; this is shown in Figure (2.1a&b). Force is a vector and has both a magnitude and direction. The forces of push and pull are called contact forces because of the physical contact between the objects. There are, however, some other forces between objects which are not in physical contact. These forces are called non-contact forces, among these is the force between earth and the moon as shown in Figure (2.2). The unit of force measurement in the metric (SI) system is the **Newton**.



**Figure (2.1)** (a) A force  $\vec{F}$  is a push or (b) pull on an object.

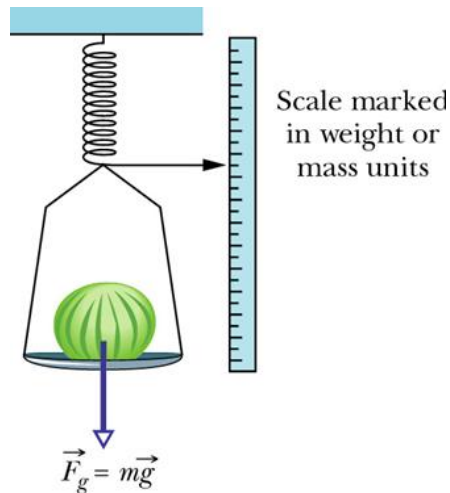


**Figure (2.2)** The non contact force  $\vec{F}_m$  between the earth and moon. Credit: “*Physics for scientists and engineers a strategic approach*” by Randall D. Knight Pearson-Addison Wesley 2004.

## 2.2 Some Common Forces

### 2.2.1 Earth's Gravitational Force (weight)

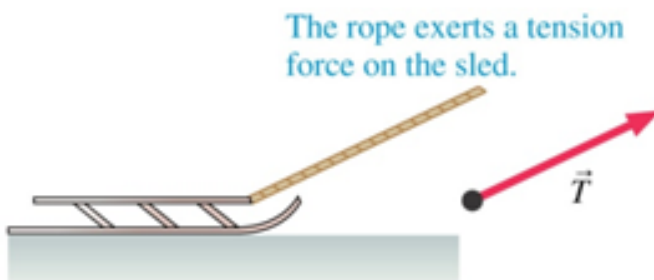
Gravitational force  $\vec{F}_g = \vec{w} = m\vec{g}$  is the gravitational pull of the earth on any object, at rest or in motion, on or near the surface of the earth. It is directed toward the center of earth and represents the **weight**  $\vec{w}$  of the object.



**Figure (2.2)** Gravitational force is a downward pull towards the earth's center. Credit: *Fundamental of physics,* By Halliday, Resnick, and Walker," 6<sup>th</sup> Ed. John Willey & Sons, 2001.

### 2.2.2 Tension Force

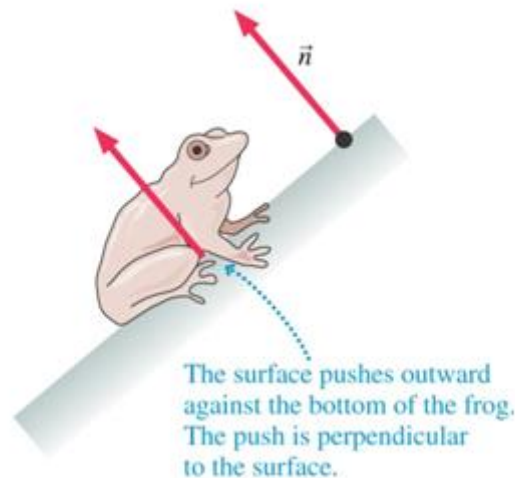
**Tension force** is a contact force (pull) provided by a string, rope, or wire on an object. The direction of the tension, which is written as  $\vec{T}$  is always in the direction of the rope or wire as shown in Figure (2.3).



**Figure (2.3)** Tension force  $\vec{T}$  provided by a rope on an object (sled). Credit: *Physics for scientists and engineers a strategic approach,* by Randall D. Knight Pearson-Addison Wesley 2004.

### 2.2.3 Normal Force

**Normal force**  $\vec{n}$  is force provided by a surface (table or wall, for example) against an object that is pressing on the surface. Normal force is always points vertically upward to the surface. Figure 2.4 shows an example of normal force.



**Figure (2.4)** Normal force  $\vec{n}$  provided by the surface on an object (frog). The black dot represents the object on which the normal force is acting. Credit: “*Physics for scientists and engineers a strategic approach*,” by Randall D. Knight, Pearson-Addison Wesley 2004.

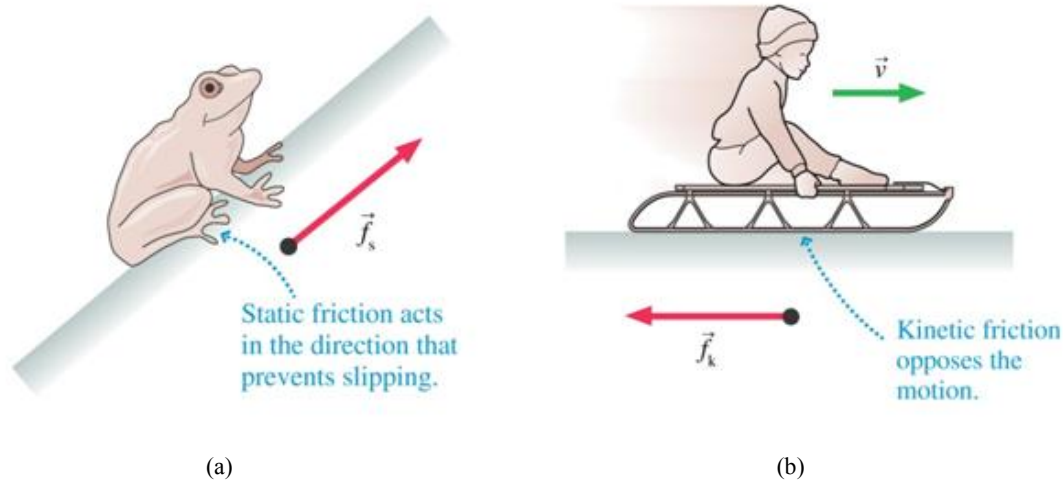
### 2.2.4 Friction Force

**Friction force**  $\vec{f}$  is a force provided by a surface (table or wall, for example) against any attempt to move an object along the surface in contact with. Unlike the normal force, friction force is parallel to the surface. The rougher the surface is, the larger the friction.

There are two different kinds of friction force:

- *Static friction*  $\vec{f}_s$  is force that prevents the object from sliding over the surface and thus it resists motion. The direction of  $\vec{f}_s$  is always opposite the direction the object would move if there is no friction.
- *Kinetic friction*  $\vec{f}_k$  is the force that opposes the motion of the object already in motion. The direction of  $\vec{f}_k$  is opposite to the motion.

Figure (2.5a&b) shows both static and kinetic friction respectively.



**Figure (2.5)** (a) Static and (b) kinetic friction force provided by a surface on an object in contact with. Credit: “*Physics for scientists and engineers a strategic approach*,” by Randall D. Knight, Pearson-Addison Wesley 2004.

### 2.2.5 Combining Forces: The Net (resultant) Force $\vec{F}_{net}$

In many cases, a group of two, three, or more forces act on an object. Each force tends to pull or push the object to specific direction. The **net force**  $\vec{F}_{net}$  is a single force resulted from combining all the forces such that it represents their net effect.

To find  $\vec{F}_{net}$ , we will follow the convention

- All the forces to the right of the origin (0) of the coordinate system as positive forces and those to the left as negative as forces. Similarly,
- All forces directed upward as positives and downward forces as negatives

#### Free Body Diagram (FBD)

To solve problems with  $\vec{F}_{net}$ , it is very helpful, and highly recommended, to make a sketch or a free body diagram (FBD) of the problem. This process will help the student to identify all the forces acting on the object in order to solve for  $\vec{F}_{net}$ . The following example illustrates this procedure.

#### Example 2.1

Draw a free body diagram of a box resting on a table top.

Solution

Consider Figure (2.6). The procedure of FBD can be outlined as follows

1. Identify all the forces acting on the object (box).
2. Draw a coordinate system.
3. Represent the object as a dot.
4. Draw vectors that represent the forces acting on the object
5. Draw and label the  $\vec{F}_{net}$  close to the diagram (b)

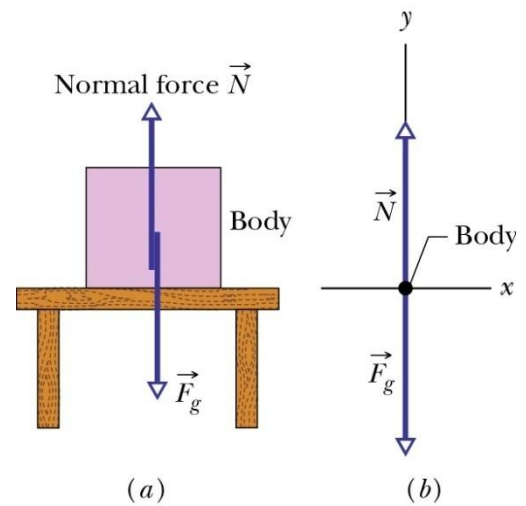


Figure (2.6): (a) A box resting on a table top and (b) its free body diagram. Credit: *Fundamental of physics,* By Halliday, Resnick, and Walker, 6<sup>th</sup> Ed. John Wiley & Sons, 2001.

There are two forces acting on the object's (box), normal force  $\vec{N}$  upward and weight  $\vec{w} = \vec{F}_g$  downward. Following the rules, the tension  $\vec{N}$  is positive and the weight  $\vec{w} = \vec{F}_g$  is negative. The net force acting on the object is therefore  $\vec{F}_{net} = \vec{N} - \vec{F}_g$

### Example 2.2

Find the net (resultant) force acting on the object as shown in the drawing below. Draw FBD first and then solve for the net force

Solution

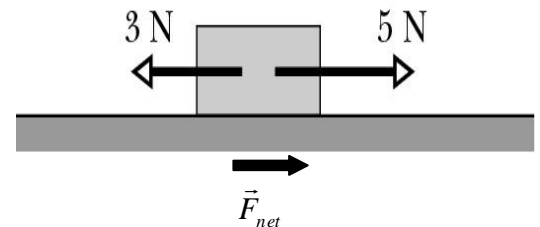
FBD:  $F_2 = 3N$   $F_1 = 5N$

Given Data:  $F_1 = 5N, F_2 = 3N$

Wanted:  $\vec{F}_{net}$

$$\therefore F_{net} = F_1 - F_2$$

$$\therefore F_{net} = 5N - 3N = 2N \quad \text{to the right}$$

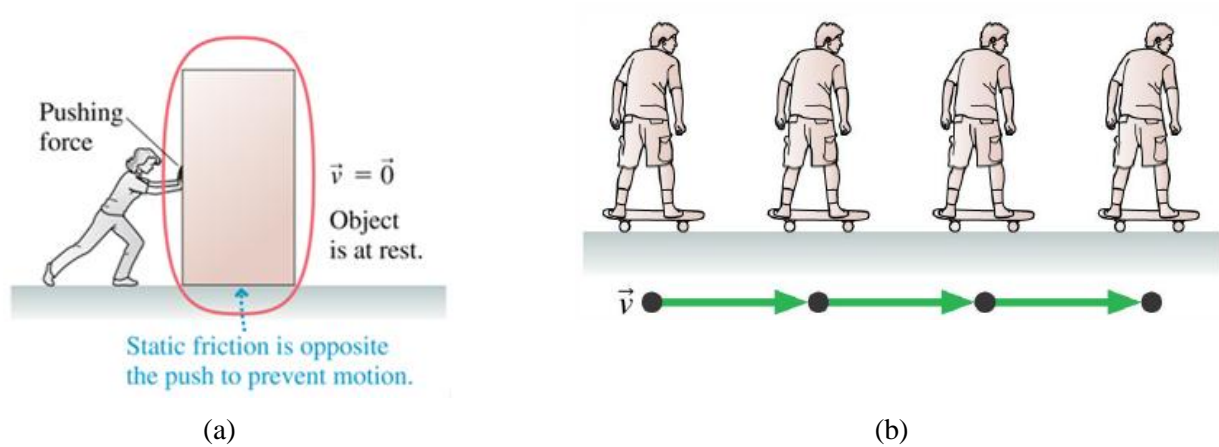


### 2.3 Balanced and Unbalanced Forces

**Balanced forces** are forces that add up to zero or their net force  $\vec{F}_{net} = 0$ . This implies that

- An object at rest stays at rest
- Moving object will move with zero acceleration (constant velocity)

Figure (2.7a&b) shows two examples of objects under balanced forces



**Figure (2.7)** (a) an object at rest and under balanced forces. (b) an object moves at constant velocity and under balanced forces. Credit: “*Physics for scientists and engineers a strategic approach*,” by Randall D. Knight Pearson-Addison Wesley 2004.

**Unbalanced forces** are forces that do not add up to zero, or their net forces  $\vec{F}_{net} \neq 0$ . This implies that

- Unbalanced forces cause an object to start moving, stop moving, or change direction
- Unbalanced forces accelerate objects

Figure (2.8) shows an object (rocket) moving under the act of unbalanced force.



**Figure (2.8)** Motion of an object (rocket) due to unbalanced force. Credit: “*Integrated science*”, by B.W. Tillery, E. D. Enger, and F. C. Ross, 3<sup>rd</sup> Ed., McGraw Hill 2004.

## 2.4 Mass and Inertia

The *mass* of an object is the amount of matter it contains. A massive truck, for example, contains more matter or mass than a bicycle. Also, you have more mass when you’re an adult than when you’re a child. Mass and weight are different concepts and their difference can be shown in two ways

- Mass is a scalar quantity that has magnitude only and can be described by a number and a unit. Weight is a vector
- Mass is constant quantity that doesn't depend on location. Weight depends on location. An astronaut's weight, for example, is less on the moon than on earth, but his 70kg mass is the same both on moon and on earth.

Weight and mass are, nonetheless, related by an equation

$$w = mg \quad (2.1)$$

Where  $g$  is the acceleration due to gravity. Close to earth,  $g = 9.8 \text{ m/sec}^2$

**Inertia**, another property of matter like mass, is defined as the natural tendency of any object to remain at rest or in motion at a constant speed along a straight line. From this definition, we can see that inertia represents a resistance against any attempt to change the object's motion ( $v = 0$ , or  $v \neq 0$ ).

The Inertia concept was developed by Galileo and then used by Newton. According to Galileo, a rolling ball on a frictionless track will move by its inertia with a constant speed and along a straight line and never stops. The ball's inertia, in this case, is its propeller force, which maintains its motion, but in reality, friction force, which cannot be ignored, overcomes the ball's inertia and brings it to stop.

There is a close association between mass and inertia. For example, larger mass has larger inertia than lighter mass. A truck has more inertia than a bicycle.

### Example 2.3

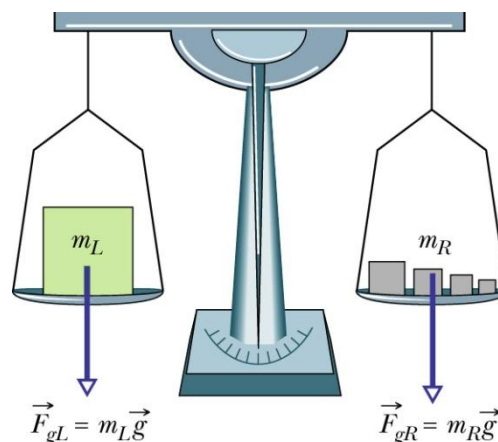
How much is the mass  $m_R$  required to balance the object on the left side, which weighs 600N?

Solution

$$\therefore F_{gL} = F_{gR},$$

$$\therefore 600\text{N} = (m_R)(9.8\text{m/sec}^2)$$

$$\therefore m_R = 61.22\text{kg}$$



**Sketch credit:** Halliday, Resnick, and Walker, "Fundamental of physics" 6<sup>th</sup> Ed. John Wiley & Sons, 2001.

## 2.4 Newton's Laws of Motion

Newton developed three laws that completely describe motion.

### 2.4.1 Newton's First Law (the law of inertia)

The first law can be stated as follows: If the net force  $\vec{F}_{net}$  acting on an object is zero, then the object remains at rest (if initially at rest) or moving continuously with constant velocity (if initially moving) along straight line.

Newton's first law considers the following:

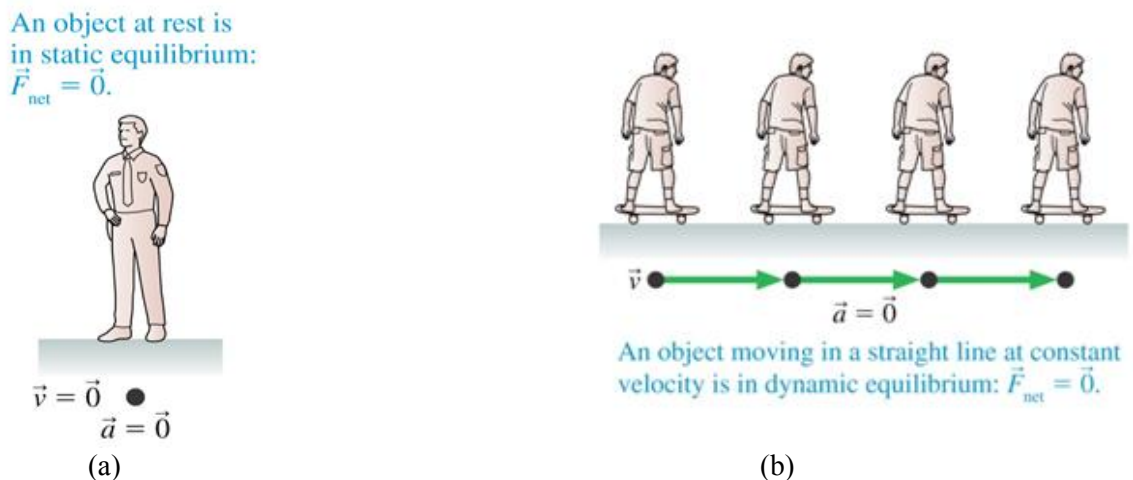
- Balanced forces  $\vec{F}_{net} = 0$  (or  $\vec{a} = 0$ ), also
- $\vec{F}_{net} \neq 0$  causes acceleration or changes an object's velocity

### Mechanical Equilibrium

An object on which  $\vec{F}_{net} = 0$  or  $\sum F = 0$ , is said to be in **mechanical equilibrium**. There are two kinds of mechanical equilibrium:

- Static equilibrium. The object remains at rest.
  - Dynamic equilibrium. The object moves at constant velocity along straight line.
- Figure 2.6 shows static and dynamic equilibrium.

Figure (2.9) shows two examples of static and dynamic equilibrium.



**Figure 2.9:**(a) static and (b) dynamic equilibrium. Credit: “Physics for scientists and engineers a strategic approach” by Randall D. Knight Pearson-Addison Wesley 2004.

**Example 2.4**

A 50 kg box is suspended from the ceiling by a rope as shown in the drawing below. Draw a free body diagram and find the force of tension in the rope

Solution

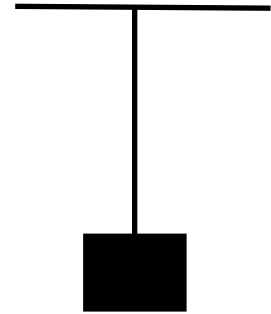
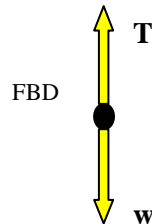
Given Data:  $m = 50\text{kg}$ , wanted: FBD, T

$\therefore$  static equilibrium

$$\therefore \vec{F}_{net} = \sum F = 0$$

$$\therefore T - w = 0, \text{ or}$$

$$T = w = mg = (50\text{kg})(9.8\text{m/sec}^2) = 490\text{N}$$

**2.4.2 Newton's Second Law**

The second law can be stated as follows: If the net force  $\vec{F}_{net} \neq 0$ , then an object of mass  $m$  will move with acceleration  $\vec{a}$  such that

$$\vec{a} = \frac{\vec{F}_{net}}{m}, \text{ or}$$

$$\vec{F}_{net} = m\vec{a} \tag{2.2}$$

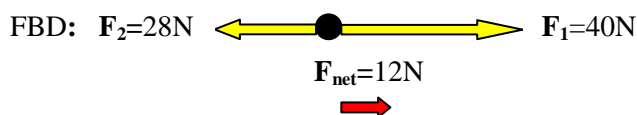
Newton's second law considers the followings

- $\vec{F}_{net}$  is the cause of acceleration
- $\vec{a}$  is directly proportional to  $\vec{F}_{net}$  and is inversely proportional to  $m$
- $\vec{a}$  and  $\vec{F}_{net}$  are always in the same direction (direction of  $\vec{F}_{net}$ )

**Example 2.5**

Two forces of 40 N and 28 N acting on an object of mass 3 kg s shown below. Does the object have acceleration? If it has then find its magnitude and its direction. Draw a free body diagram.

Solution



Given Data:  $F_1=40\text{N}$ ,  $F_2=28\text{N}$ , Wanted  $\vec{a}$

$$F_{net} = 40\text{N} - 28\text{N} = 12\text{N}, \quad \text{to the right}$$

$$\therefore a = \frac{F}{m}$$

$$\therefore a = \frac{152\text{N}}{3\text{kg}} = 4\text{N/kg or } 4\text{m/s}^2 \text{ to the right}$$

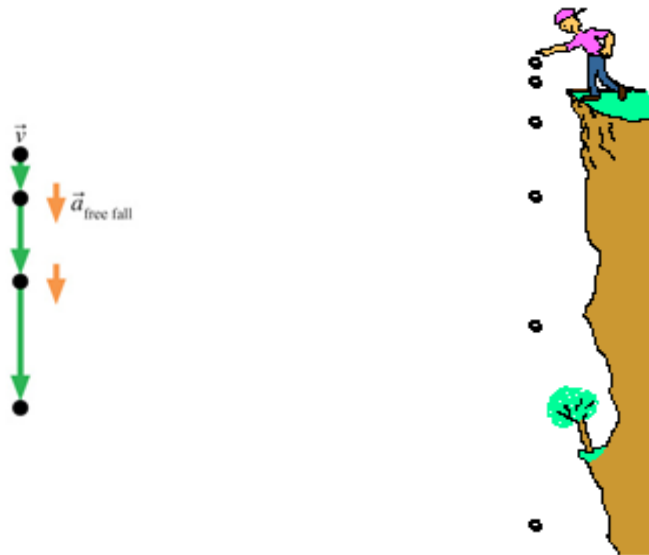
### Mass and acceleration

Mass is inversely proportional to the acceleration, therefore by doubling the mass and keeping the force unchanged will reduce the acceleration into a half its value. Therefore, mass is a property of an object that measures its resistance to acceleration. By this, it means that mass is a measure of inertia. The larger the mass, the larger the inertia or resistance to change to motion, and the smaller the acceleration.

### Free Fall Motion: Motion with $a = g$

**Free fall motion** is motion in which the only force acting on the object is gravity. under the force of gravity only. Under this condition, the free fall motion implies the following

- Air resistance is small and can be ignored
- All objects will fall with the same acceleration of gravity regardless of their masses. Therefore, they reach ground at same time
- Free fall motion is not uniform (constant). Each second in the air, the velocity or speed increases by  $9.8\text{m/sec}$ . Therefore, the path of the falling object looks like the pattern shown in Figure (2.10)



**Figure (2.10)** The pattern of fall of free fall motion. The distance between successive moments increases with time.

**Example 2.6**

A ball is dropped from the top of building and hits the ground below as depicted below. If the time of fall is 5 seconds then find the ball speed the moment it hits the ground. Ignore air resistance

Solution

Given Data:

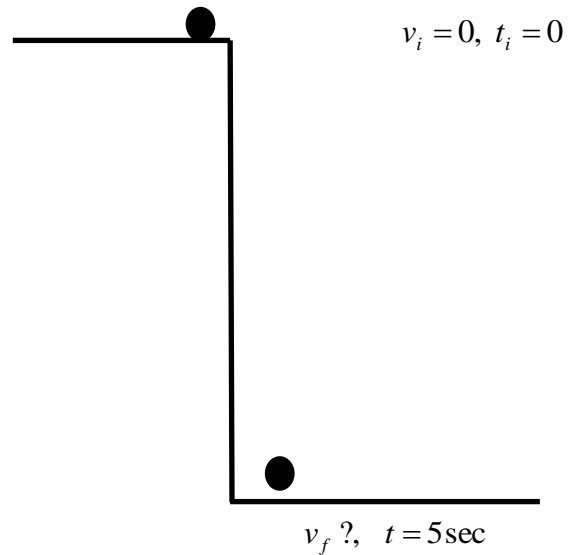
$$v_i = 0, t_i = 0, t_f = 5 \text{ sec,}$$

wanted :  $v_f$

$$\text{Free fall} \Rightarrow F = W = mg$$

wanted :  $v_f$

$$v_f = 49 \text{ m/sec (how?)}$$



**Terminal Speed:** Falling with air resistance (  $a = 0$  )

Normally, a falling object in the air is acted on by air resistance  $\vec{F}_{air}$  as well as gravity  $\vec{F}_{grav}$  as shown in Figure. When the air resistance balances the force of gravity (weight), the object moves with uniform (constant) speed called **terminal speed**. Figure (2.11) depicts objects moving with terminal speeds.

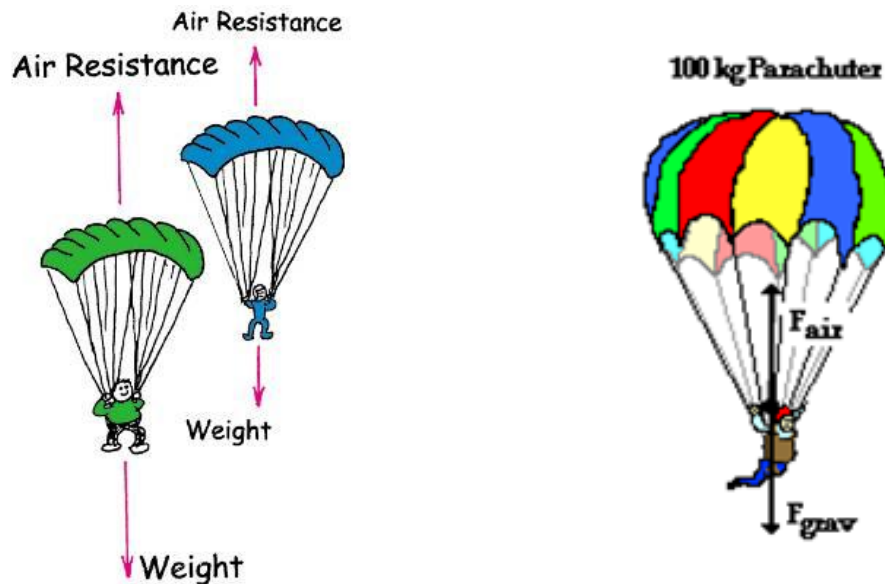
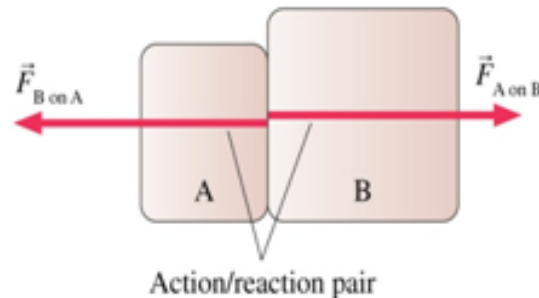


Figure (2.11) Objects (sky divers) moving with terminal speeds.

### 2.4.3 Newton's Third Law (action-reaction law)

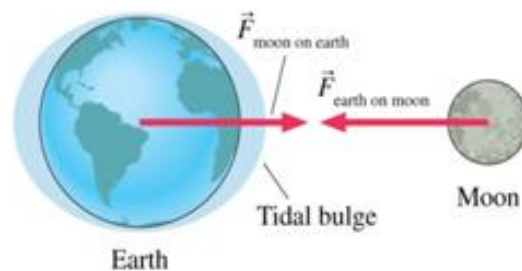
The law can be stated as follows: If object A exerts a force on object B, object B exerts a force on A that is equal in magnitude and opposite in direction as is shown in Figure 2.12. Mathematically, the law can be written as

$$\vec{F}_{A \text{ on } B} = -\vec{F}_{B \text{ on } A} \quad (2.3)$$



**Figure (2.12)** Action and reaction forces between interacted objects . Credit: “*Physics for scientists and engineers a strategic approach*,” by Randall D. Knight Pearson-Addison Wesley 2004.

The force between the earth and moon is another example of action and reaction pair of forces.



Newton's third law implies the following

- Forces always occur in pairs
- Both action and reaction forces occur simultaneously and either can be called action and the others a reaction
- The forces act on different objects. Therefore, action and reaction never balance each other

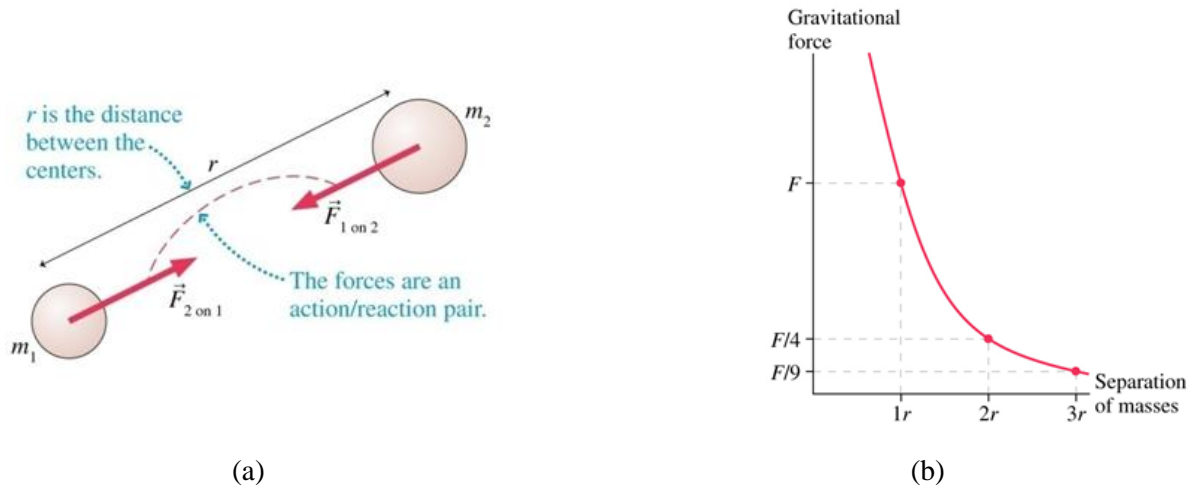
## 2.5 Newton's Law of Universal Gravitation

**Newton's third law** states that any two objects in the universe attract each other with a force that is

- Proportional to the product of their masses  $m_1$  and  $m_2$ , and

- Inversely proportional to the square of the distance between them

Figure (2.13) shows the force between the two masses and the behavior of the force with the distance of between them  $r$ .



**Figure 2.13**(a) The force between two masses separated by distance  $r$ . (b) behavior of the force with the distance  $r$ .

The mathematical description of the force can be written as

$$F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \frac{Gm_1m_2}{r^2} \quad (2.4)$$

The constant  $G$  is called the gravitational constant. In the metric (SI) system of units,  $G$  has a value

$$G = 6.67 \times 10^{-11} \text{ Nm}^2 / \text{kg}^2$$

## Chapter 2 Summary

A **force** is any pull or push to change an object position and causes a change in its motion (from speed zero to some value, for example), its direction, or both. If **friction** is eliminated, then once the motion started, a force is not necessary to keep the object moving. The object moves forever by virtue of its inertia imposed initially by the application of force. **Inertia** is a property of all objects that express their tendency to resist any attempt to move the object or to accelerate (change of motion) it. **Newton's first law**, also called the law of inertia, describes the condition imposed on objects for which all the applied forces are balanced. **Balanced forces**, a group of forces acting on an object, has a zero resultant and, thus, do not change the motion or direction of the motion. **Mechanical equilibrium** is a result of the act of balanced forces. **Newton's second law** describes the behavior of an object under the influence of unbalanced forces. **Unbalanced forces** will accelerate the object; changing its velocity, its velocity direction, or both. If accelerated, the object's mass is inversely proportional to the unbalanced force. **Free fall motion** is a special kind of motion in which the only force acting on the object is the force of gravity. Falling with air resistance, however, introduces terminal speed. **Terminal speed** is speed with  $a = 0$  resulted from the balance of air resistance and gravity forces. **Newton's third law** introduces a new definition of a force. Forces are a result of interaction among objects in contact interaction and/or action at a distance interaction. In Newton's third law, action and reaction forces between two different objects are equal in magnitude and oppositely directed. **Newton's universal law of gravitational** is a result of Newton's third law, which applies universally to any two masses in the universe at separation. The force is directly proportional to the product of the masses and inversely proportional to the squared of the distance of separation.

### Basic principles

1. Balanced forces do not cause acceleration, or change in motion.
  - 1.1  $a = 0$ , object is at rest.
  - 1.2  $a = 0$ , object moves with constant velocity along straight line.
2. Unbalanced forces cause acceleration  $a$ , or change in motion (both magnitude and direction).
  - 2.1  $a$  is directly proportional to net force.
  - 2.2  $a$  is inversely proportional to mass.
3. Free falling objects fall under gravity only.
  - 3.1 If dropped from rest, all objects will reach the ground at the same speed and acceleration regardless of their mass.
  - 3.2 Air resistance is ignored.
4. Falling with air resistance eliminates acceleration.
  - 4.1 heavy objects fall faster than light objects.
5. Forces always come in pairs. There are no single forces.

**Basic equations**

$$w = mg \quad (2.1)$$

$$a = \frac{F_{net}}{m}, \quad \text{or} \quad F_{net} = ma \quad (2.2)$$

$$F_{AonB} = F_{BonA} \quad (2.3)$$

$$F_{1on2} = F_{2on1} = G \frac{m_1 m_2}{r^2} \quad (2.4)$$

**Chapter 2 Worksheet**

**Part 1 Matching:** Match the definitions with the given concepts.

1. Newton's third law    2. Mass    3. Acceleration    4. Force    5. Newton's first law  
 6. Weight    7. Inertia    8. Free fall    9. Mechanical Equilibrium    10.  $9.8\text{m/s}^2$     11. Friction  
 12. Normal force    13. Newton

- A. \_\_\_\_\_ Is the condition where.  $\vec{F}_{net} = 0$
- B. \_\_\_\_\_ Is the amount of matter of an object or a measure of its inertia;
- C. \_\_\_\_\_ Is the unit of force.
- D. \_\_\_\_\_ Is how much is the acceleration of gravity.
- E. \_\_\_\_\_ Is meant that a force causes acceleration.
- F. \_\_\_\_\_ Is the downward pull of gravity on an object.
- G. \_\_\_\_\_ For any action there is an opposite and equal in magnitude reaction.
- H. \_\_\_\_\_ Is force divided by mass.
- I. \_\_\_\_\_ Is the tendency to resist any attempt to change motion or acceleration
- J. \_\_\_\_\_ Is the force that prevents any attempt to slide or the motion of an object.
- K. \_\_\_\_\_ Is the motion under the force of gravity only.
- L. \_\_\_\_\_ Is the perpendicular force exerted by a surface on any object attached to it..
- M. \_\_\_\_\_ Is any push or pull on an object.

**Part 2: general review questions: write your answers on a separate sheet**

1. Does a bicycle have more inertia than a truck? Explain
2. Use your own words (do not look at the text), define Newton's first law.
3. When the same force is applied to two different masses, which will have a greater acceleration? Explain?
4. Explain how the weight of a person is different on the moon than on the earth. Would the person's mass be different? Explain
5. In your own words (do not look at text), define Newton's third law.
6. Why do you move forward when your car comes to a stop? Refer to one of Newton's law.
7. The net force acting on an object is zero. Is it possible for the object to move with a velocity that is not zero? Explain
8. Is the free fall motion is under constant acceleration of  $9.8\text{m/s}^2$ , or constant velocity of  $9.8\text{m/s}$ ? Explain
9. Newton's second law states that when a net force is applied on an object, it must accelerate. Does this means that when two or more forces act at the same time, it must accelerate? Explain
10. According to Newton's third law, when a person push on an object, the object pushes back on the person with an oppositely directed force of equal magnitude. If the object is a massive truck resting on the ground, it will probably not move. Some people think that the reason the truck does not move is that the two oppositely directed pushing forces cancel. Explain why this explanation is not correct and why the truck does not move?
11. Assume air resistance exists and acts on object in the air. Draw a free body diagram showing all the forces acting on a ball thrown vertically upward in the air.
12. A stone is dropped from the top of a building. On its way down in the air is it in equilibrium? Explain (ignore air resistance)
13. If an object has no acceleration, is it correct to say that no forces are acting on the object? Explain
14. If the acceleration of an object is zero, does this means that there are no forces acting on it? Explain
15. The force of gravity on a 2kg rock is twice as great as that on a 1 kg rock. Why then doesn't the heavier rock fall faster? Explain
16. A person exerts an upward force of 60 N to hold a bowling ball. Describe the reaction force by stating (a) its magnitude, (b) its direction, (c) on what body it is exerted, and (d) by what object it is exerted.

17. When you stand still on the ground, how large a force does the ground exert on you? Why doesn't this force make you rise up into the air? Explain
18. Ali's mass is 70 kg on earth. What are his (a) mass and (b) weight on Mars, where  $g = 3.72m/s^2$ .
19. Yasir has a mass of 45 kg on earth. What are his (a) mass and (b) weight on Jupiter, where  $g = 25.9m/s^2$ .
20. Why do objects that experience air resistance finally reach a terminal velocity?

### Part3: Multiple Choices

1. If an object is moving with constant velocity along a straight line, then
  - A. No forces acting on the object.
  - B. Single constant force acting on the object in the direction of motion.
  - A. Single force acting on the object in the opposite direction.
  - B. A net force of zero acting on the object.
2. Force
  - A. Is a vector quantity.
  - B. May be different from weight.
  - C. Does not always cause motion.
  - D. All of the above is correct.
3. Mass and weight
  - A. Are the same.
  - B. Are different.
  - C. Do not change wherever you are.
  - D. None of the above is correct.
4. According to Newton's second law
  - A. Force is equal to mass times acceleration.
  - B. Acceleration equals mass times force.
  - C. Mass equals to force times acceleration.
  - D. None of the above is correct.
5. Friction
  - A. Always acts parallel to the surface of contact and opposite to the direction of motion.
  - B. Acts in the direction of motion.
  - C. Is smaller when starting than moving.
  - D. In reality, there is no friction force.
6. Which matter property explains why tapping your toothbrush on the sink dry it off?
  - A. Weight.
  - B. Volume.
  - C. Acceleration.
  - D. Inertia.

7. When you kick a football, the ball pushes on you
  - A. Harder.
  - B. Lesser.
  - C. With zero force.
  - D. None of the above is correct.
8. When a person begin to move forward, which force allows him to accelerate
  - A. Weight.
  - B. Normal force.
  - C. Air resistance.
  - D. Friction.
9. If the distance of separation between two masses is reduced in to a half, then the force of gravity will be
  - A. Reduced by 4 times.
  - B. Reduced by 1/4
  - C. Increased by 4 times.
  - D. Increased by 1/4.

**Part4: True/False** (If your answer is F, then try to correct the statement)

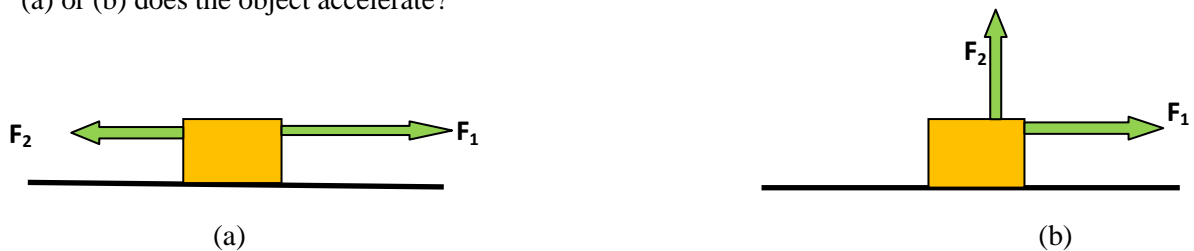
1. The action and reaction forces act on the same object and therefore they cancel each other.
  - A. True
  - B. False
2. If net force acting on an object is not zero, then the object will accelerate.
  - A. True
  - B. False
3. Acceleration causes a net force.
  - A. True
  - B. False
4.  $G$  and  $g$  are the same.
  - A. True
  - B. False
5. The mass is the downward pull on an object by gravity.
  - A. True
  - B. False
6. Weight is the amount of matter an object contains.
  - A. True
  - B. False
7. Mass is the resistance of an object to acceleration.
  - A. True
  - B. False
8.  $\vec{a} = 0$  is the condition for mechanical equilibrium.
  - A. True

B. False

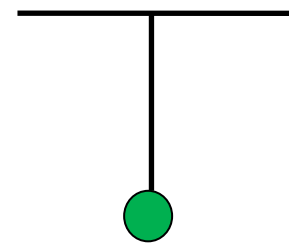
9. A free-body diagram represents the object as a dot at the origin of a coordinate system.  
 A. True  
 B. False
10. Force is either a contact (push or pull) force or a non-contact (long-range) force.  
 A. True  
 B. False

### Part 5: Exercises

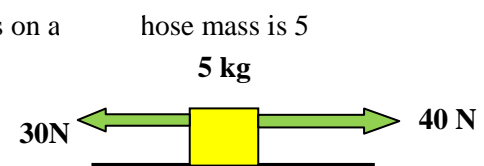
1. Two equal forces of 20 N acting on the object shown in the diagram below. In part (a) the two forces are acting horizontally and opposite to each other. In part (b), the two forces are perpendicular to each other. If these are the only forces acting, then in which part of the diagram (a) or (b) does the object accelerate?



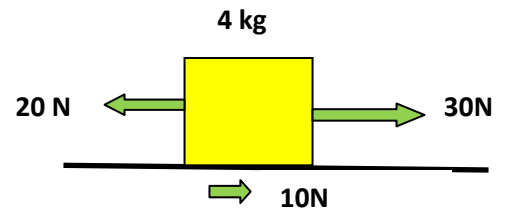
2. A ball of mass  $m$  hangs from a rope attached to a ceiling, as shown in the diagram below. Draw a free body diagram and answer the following
- (a) What forces act on the ball? How many?  
 (b) What is the net force acting on the ball? Explain  
 (c) For each force identified in part (a), what is the reaction force?



3. Two forces, one is 40 N and the other is 30 N act in opposite directions on a kg. Find the box's acceleration.



4. A 4 kg box is acted upon by three forces as shown in the diagram below.
- (a) What is the net force acting on the box and in which direction?  
 (b) What is the acceleration of the box?



### Part 6: Challenge Exercises

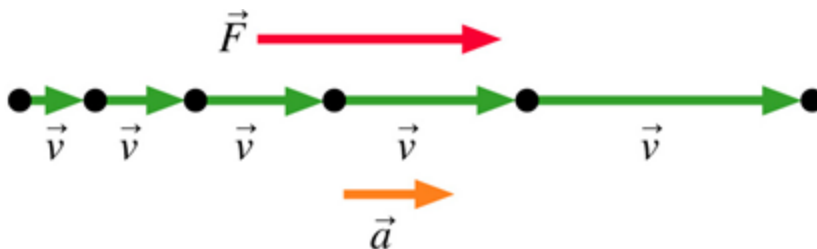
- Suppose you travel into deep an empty space and throw a rock as shown in the drawing below.

The rock will (explain)

- gradually stop, or
- Continue in motion in the same direction at constant speed.



- Prove that in free fall motion all objects regardless of their mass accelerate with the same acceleration  $a = g$ .
- An object whose free body diagram is shown in the diagram below is acted upon by a force  $\vec{F}$ . According to the diagram is the object speeding up or slowing down? Explain



- The drawing below shows a free body diagram of two forces acting on an object.
  - Is the object in equilibrium? Explain
  - If it is not in equilibrium, then add a third force and bring it into equilibrium.

