**PHY 101 BY Mr. Oluwadare O. J**

**Topic: Newton’s Laws of Motion**

**Rigid Body**

A body is said to be *rigid,* if the relative position of any two particles in it do not change under the action of the forces. The mechanics of the rigid bodies dealing with the bodies at rest is termed as **Statics** and that dealing with bodies in motion is called **Dynamics**. The dynamics dealing with the problems without referring to the forces causing the motion of the body is termed as **Kinematics** and if it deals with the forces causing motion also, is called **Kinetics.**

**NEWTON’S LAWS OF MOTION**

The relationship of motion to the forces that cause it is very important here. The concepts of force and mass are suitable to analyze the principles of dynamics. These principles were clearly stated for the first time by Sir Isaac Newton, today we call them Newton’s laws of motion. The first law states that when the net force on a body is zero, its motion doesn’t change. The second law relates force to acceleration when the net force is not zero. The third law is a relationship between the forces that two interacting bodies exert on each other.

Newton’s laws are the foundation of **classical mechanics** (also called **Newtonian mechanics**); using them, we can understand most familiar kinds of motion. Newton’s laws need modification only for situations involving extremely high speeds (near the speed of light) or very small sizes (such as within the atom).

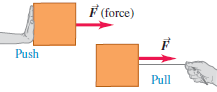
**Force and Interactions**

A **force** is a push or a pull. A better definition is that a force is an *interaction* between two bodies or between a body and its environment.

That’s why we always refer to the force that one body *exerts* on a second body.

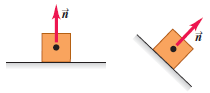
When you push on a car that is stuck in the snow, you exert a force on the car; a steel cable exerts a force on the beam it is hoisting at a construction site; and soon. A force is a *vector* quantity; you can push or pull a body in different directions.

When a force involves direct contact between two bodies, such as a push or pull that you exert on an object with your hand, we call it a **contact force.**

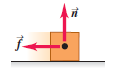


**Type of Contact force**

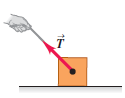
**Normal force (N)**: This is the force exerted on an object by any surface with which it is in contact. The *normal* means that the force always acts perpendicular to the surface of contact, no matter what the angle of that surface. see figure 1

Figure 1

**Friction force (F):** Thisis the force exerted on an object by a surface acting parallel to the surface, in the direction that opposes sliding. see figure 2

Figure 2

**Tension force (T)**: The pulling force exerted by a stretched rope or cord on an object to which it’s attached. see figure 3

Figure 3

**Long-Range Forces**

There are **long-range forces** that act even when the bodies are separated by empty space. The force between two magnets is an example of a long-range force, the force of gravity (Figure 4 below); the earth pulls a dropped object toward itself even though there is no direct contact between the object and the earth. The gravitational force that the earth exerts on a body is called the **weight.** see figure 4

To describe a force vector, we need to describe the *direction* in which it acts as well as its *magnitude,* the quantity that describes “how much” or “how hard” the force pushes or pulls. The SI unit of the magnitude of force is the *newton,*

Figure 4

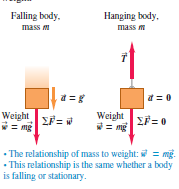
**Mass and Weight**

The quantity of the matter possessed by a body is called mass. It changes as a result of deformation in materials. The force that makes the body accelerate downward is its weight. The weight of an object may change due to change in gravitational force. Even the body may become weightless when gravitational force vanishes but the mass remain the same. Mass m and weight w of an object are related with the equation

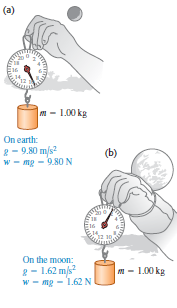
(1)

where is a constant known as the acceleration due to gravity having a magnitude

**Relationship between mass and weight**

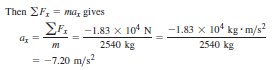


Measuring mass and weight



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The following are the Newton’s laws of motion:

1. Newton’s first law
2. Newton’s second law
3. Newton’s third law
4. Newton’s law of gravitation

**Newton’s First Law (Law of inertia)**

*This first law states that: “If an object is at rest then it will remain at rest or if it is moving along a straight line with uniform speed then it will continue to keep moving unless an external force is applied on it to change its existing state.”*

*It states that everybody continues in its state of rest or of uniform motion in a straight line unless it is compelled by an external agency acting on it.*

This leads to the definition offorce as the external agency which changes or tends to change the state of rest or uniformlinear motion of the body. It is matter of common experience that a body at rest will remain at rest if the resultant force acting on it is zero. When a body is acted on by zero net force, it moves with constant velocity and zero acceleration. E.g. a boy standing on the field tract will remain unless a force in form of a pull or a push is exerted on him.

This law also explains why an un-disturbed body moves in a straight line with constant or uniform velocity. Thus this tendency of bodies to remain in their state of rest or of uniform straight line motion in absence of any external forces is termed as Inertia. The more massive a body, the more its inertia and vice versa. This law also explains why a rotating fan refused to stop immediately it is being switched off.

**Newton’s Second Law (Fundamental Law of Dynamics)**

*It states that the rate of change of momentum of a body is directly proportional to the impressed force and it takes place in the direction of the force acting on it. There is a proportionality constant called mass, the proportion of the force to the acceleration that is always constant for a given object.”*

This law considers a case when the force is not zero. It is now necessary to take into account the change in the momentum per unit time as the net force applied on a body. Mathematically;

(1)

where are force in Newton, , mass in kilogram (), final velocity in metre per second (), initial velocity metre per second () and time in second (), respectively. The product and are final and initial momentum of a body, respectively.

(2)

where is a constant with a unity magnitude

In a similar way

***Newton’s Second Law states that if a net external force acts on a body, the body accelerates. The direction of acceleration is the same as the direction of the net force. The mass of the body times the acceleration of the body equals the net force vector.***

In symbols,

(Newton’s second law of motion) (3)

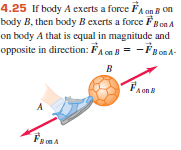
An alternative statement is that the acceleration of a body is in the same direction as the net force acting on the body, and is equal to the net force divided by the body’s mass:

(4)

Newton’s second law is a fundamental law of nature, the basic relationship between force and motion.

**Newton’s Third Law (The Law of Reaction)**

*If body A exerts a force on body B (an “action”), then body B exerts a force on body A (a “reaction”). These two forces have the same magnitude but are opposite in direction. These two forces act on different bodies. To simply put; It states that for every action there is an equal and opposite reaction.*





**Newton’s Law of Gravitation**

Everybody attracts the other body. The force of attraction between any two bodies is directly proportional to their masses and inversely proportional to the square of the distance between them. According to this law the force of attraction between the bodies of mass *m1* and mass *m2* at a distance *r*

where *G* is the constant of proportionality and is known as constant of gravitation.

**Note the following**

1. Particle in equilibrium
2. Dynamic of particle

**Assignment**

1. At the surface of Jupiter’s moon Io, the acceleration due to gravity is g=1.81m/s2. A watermelon weighs 44.0 N at the surface of the earth. (a) What is the watermelon’s mass on the earth’s surface? (b) What are its mass and weight on the surface of Io?
2. An astronaut’s pack weighs 17.5 N when she is on earth but only 3.24 N when she is at the surface of an asteroid. (a) What is the acceleration due to gravity on this asteroid? (b) What is the mass of the pack on the asteroid?
3. A box rests on a frozen pond, which serves as a frictionless horizontal surface. If a fisherman applies a horizontal force with magnitude 48.0 N to the box and produces an acceleration of magnitude 3.00 m/s2 what is the mass of the box?
4. A dock worker applies a constant horizontal force of 80.0 N to a block of ice on a smooth horizontal floor. The frictional force is negligible. The block starts from rest and moves 11.0 m in 5.00 s. (a) what is the mass of the block of ice? (b) If the worker stops pushing at the end of 5.00 s, how far does the block move in the next 5.00 s?
5. A crate with mass 32.5 kg initially at rest on a warehouse floor is acted on by a net horizontal force of 140 N. (a) what acceleration is produced? (b) How far does the crate travel in 10.0 s? (c) What is its speed at the end of 10.0 s?