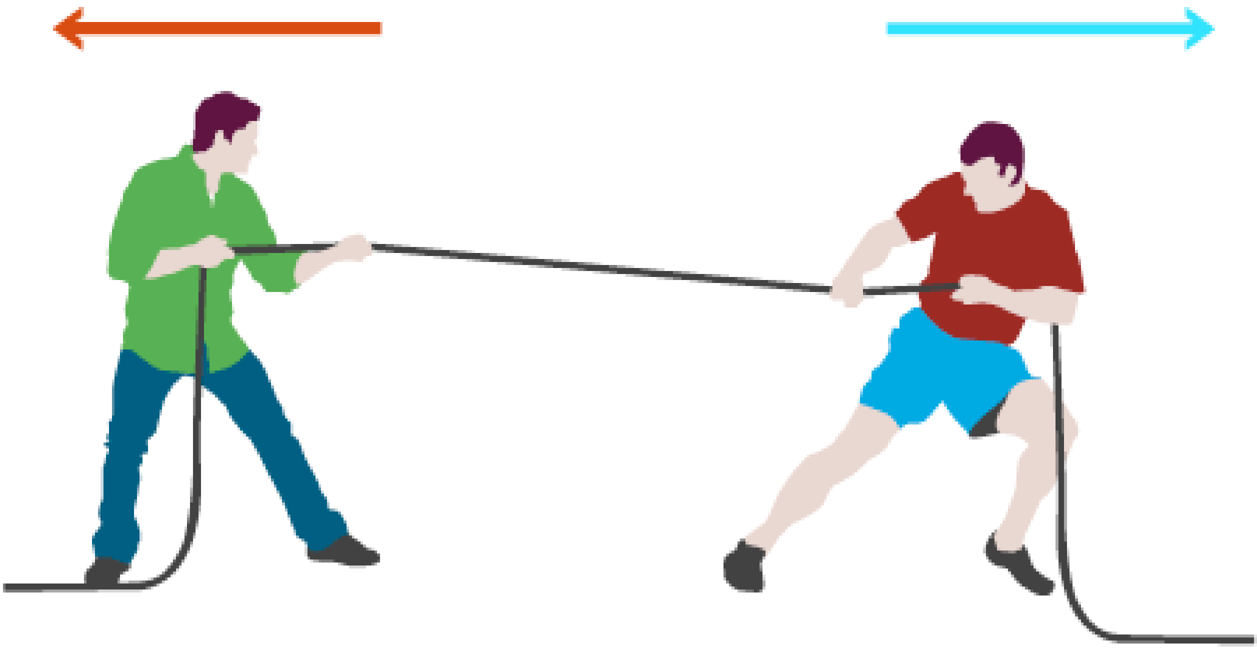
Genius Nepal

A First Course on Force



www.geniusnepal.com

A First Course on Force

About the Book

This chapter has been extracted from book by geniusnepal. This book is targeted for the students of class 8, 9, 10 for helping them in understanding force. We believe this book to be different than those you have encountered so far. Different in a sense that, it does not include exercises and does not follow any specific language; although most of the text is written in English, to make you understand we have also included *Devanagari* script at some instances. We are more focused to make students understand the concepts and ideas, so priorities have been given in writing *simple- spoken type* English which sometimes have even violated the rules of Grammar.

Making students understand is the greatest challenge that stands before every teacher and every writer. Our experiences till date that we have achieved while pursuing our goal, teach us that, it is next to impossible to visualize the concepts of force via text alone. So, interactive images and animation/videos are essential. We the members of geniusnepal are trying to provide you with those resources at our best. Geniusnepal is dedicated to help students achieve the best qualities, which the country at present needs the most. (Details at: *http*://geniusnepal.com).

This book doesnot substitute the *mainstream syllabus based* books used by different schools. But can be used as a good reference book. It is recommended that every student has a copy of this book as we believe it to be good in helping you grab the ideas. In this book, we have reflected what we have learnt in our course of educational voyage. This book is not an extract or copies of any other books though we may have acquired knowledge from them. So, it is solely an intellectual property of the writers.

Despite repeated proof-reading and rechecking, there may still exist mistakes in the book as it is the 1st edition and first of this kind ever written by the writers. Help us rectify it and bring out better volumes in the coming future. Help us grow.

Authors

CONTENTS

FORCE

1.1 Newton's Laws and F=ma

When you move an object on a table, it stops after a while. So, Aristotle thought that FORCE is something that must be applied continuously for moving an object.

Newton modified the concept of FORCE. When we apply force to an object on the table. It moves, but the reason for it to stop after a while is due to another force called frictional force (which acts in direction opposite to the applied force). He assumed that if the table was frictionless then once the force was applied on the object, it would move along the direction of the application of the force forever and ever. Here, force changed the velocity of an object from initial velocity (u)=0 to final velocity(v)=certain value(x).

Similarly if same newton of force is applied to the moving object from the opposite direction then, the object would stop. .i.e. the velocity of the object would change from initial velocity(u)=x to final velocity(v)=0.

But if that force was applied along the direction of the motion of the object instead of stopping would move faster. (So, even if the magnitude of force is same applying the same magnitude of the force causes different effects. Hence force not only depends upon magnitude but also in directions. So, we call it vector.) This shows that force is something that causes an object (a body with certain mass) to change its velocity.

Changing its velocity means to accelerate. So, force causes acceleration. This is Newton's 1st law. As 1st law defines what is force. But how can we know how much is the force? How do we know the quantity of the force? Newton's 2nd law provides us the formula to calculate the amount of force.i.e F = ma.

To find F = ma. Think alike:

1. Moving a heavy object needs greater force than moving a lighter object. Hence force is related with mass. More mass needs more force and less mass needs less force. Thus FORCE is directly proportional with mass.

2. We told earlier that acceleration is the change in velocity. But actually, it is more than that:

   Acceleration (a) = (final velocity(v)-initial velocity(u))/time(t)i.e. acceleration is the rate of change of velocity. But what is rate of change of velocity? Rate of change of velocity means how fast the velocity changes. Mathematically, it is the difference between final and initial velocity in 1 second of time. Hence, if we apply 5N and 20N force to an object which is initially at rest(u=0), then the object's final velocity(v1) in 1 second for 20N force is more than the final velocity(v2) in 1 second time for 5N force. i.e. force depends upon acceleration((v-u)/t).

3. Besides, mass and acceleration, force does not depend upon physical quantities like temperature, intensity, etc. i.e. force required to move an object at 40K temperature is same if the object is at 90K temperature.

4. Hence, we conclude that the expression of force(i.e. formula of force) should contain mass(m), initial velocity(u), final velocity(v) and time(t) or Mass(m), and acceleration(a). It may even contain momentum and other physical quantities but the overall unit must be (kgm/s).

5. We can replace the proportional sign by '=' and some constant. Here, the value of constant is 1 in SI unit.

Hence we came to know that F=ma and understand how newton derived this equation.

1.2 FIELD FORCE

We know that force is something that causes change. If there was no force in the world then everything in the world would remain as it used to be. There would be no wind blows, No man would walk, no birds would fly, no electron would revolve around the nucleus and earth would not revolve around the sun. The Force f=ma as we derived earlier, is the force that we observe when we push/pull an object. For this force to be applied, we need to touch an object and either push it or pull it. But, there are cases where changes occur without touching. E.g:

1. Earth is pulled by the sun due to gravitational force (here, Earth and the Sun does not touch each other)

2. Positive charge attracts negative charge and magnet attracts iron. This attraction is also an example of force, but there is not touching between charges or magnet and iron.

These two examples make us think, isn't it? How can force exist without touching? The force that causes the above examples are called the **FIELD FORCE**.

FIELD FORCES are those types of force which are caused due to fields. FIELD is the space (region) around an object where we feel/see its effect. Like: the space around the Earth where Gravitation is seen is called gravitational field. The reason behind the existence of this field of force is beyond the scope of this book.

If you couldn't understand or have any problems then *http://forum.geniusnepal.com* can be a place to post your queries and discuss your curiosities.

The presence of such fields causes force. Which is why they are called FIELD FORCE? Scientists have found 4 types of field in existence.

1. Gravitational field causing gravitational force (eg 1)
2. Electromagnetic field causing electromagnetic force (eg 2)
3. Strong Nuclear force (strongest force seen in nuclear fissions)
4. Weak nuclear force (seen in radioactivity).

Actually, there are only these 4 types of force in the nature. You may have studied frictional force and other different types of force. But actually, frictional force is an example of gravitational force and electromagnetic force. Similarly F=ma which we have seen earlier when pushing an object is an example of electromagnetic force. How??

Check the following points:

a. Even when you have touched an object with your finger, there still remains very very microscopic gap between your finger's atom/molecules and the atom/molecules of the object.

b. Mainly Electromagnetic force is seen in such situation the contains microscopic things like atoms/molecules (gravitational force is mainly seen in heavenly bodies) while other 3 forces are negligible.

c. Hence, pushing the object means the interatomic/intermolecular repulsion.

Remember: interatomic/intermolecular repulsion is an example of electromagnetic force.

1.3 Centripetal Force

Newton's first law states that "**Everybody continues in its state of rest or uniform motion in a straight line unless some external force is applied on it.**" If a body moves with some initial velocity then it continues to move with that velocity in a straight line until it is acted by an external force. So, to move a body in curved path (say circular path), force have to be applied. This force is called Centripetal force.

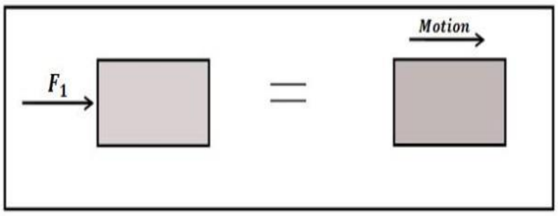


Figure 1: When force is applied on a body at rest.

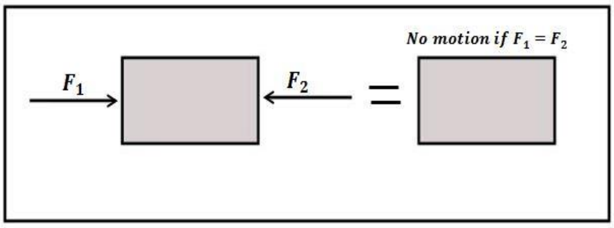


Figure 2: When two equal and opposite force acts on a body.

Let us consider a body at rest in frictionless surface as in the figure 1. Now let us apply a force (say $\boldsymbol{F_1}$) from west towards east direction. As a result, the body starts to move towards east in a straight line (towards a particular direction) continuously until and unless another force is applied. Now, if we need to change the direction of the motion of the body then we must again apply force ($\boldsymbol{F_2}$) in different direction (other than that of $\boldsymbol{F_1}$) in the moving body.

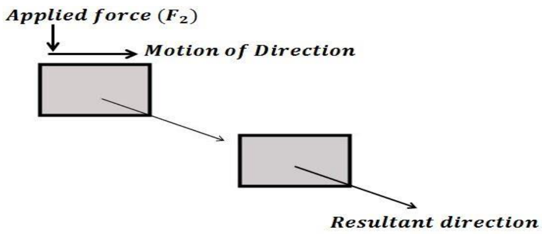


Figure 3: When a force($\boldsymbol{F_2}$) in certain direction acts on a moving body

If the magnitude of $\boldsymbol{F_2}$=$\boldsymbol{F_1}$ and the direction of $\boldsymbol{F_2}$ is from east to west then the body stops as in figure 2. But if the direction of$\boldsymbol{F_2}$isfrom north towards south then the body now starts to move towards **east-south** direction as in figure 3. Hence, in order to change the direction of the motion also, we need to apply the force in different direction other than that of the direction of original force.

CENTRIPETAL FORCE is such kind of force which is applied on a moving body so that, only the direction of the moving body is changed at every point without changing the speed of the body. So, centripetal force is that force which is applied **continuously** on a moving body to change the direction of motion. In order to move the body in circular path, the force should always be directed towards the center of the circular path.

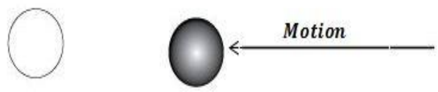


Figure 4: Motion of a body when not attached by rope.

Consider a ball is attached to the rope and rope is attached to the desk as shown in the figure 5. When we push a ball from east to west then the ball will try to move from east to west. As it tries, the rope does not allow it to move towards west. It then pulls the body towards center. Now the ball tries to move towards **south-west** direction. Again, the ball is pulled by the rope towards center so now the ball starts to move towards **south** direction as shown in the figure 6 and again the pulling of rope tends to change the direction of the ball…This process continuously occurs and as a result the ball moves in circular direction. <u>**This pulling by which the rope pulls the ball toward it's center which causes a ball to move in circular path is CENTRIPETAL FORCE IN THE CASE**</u>.

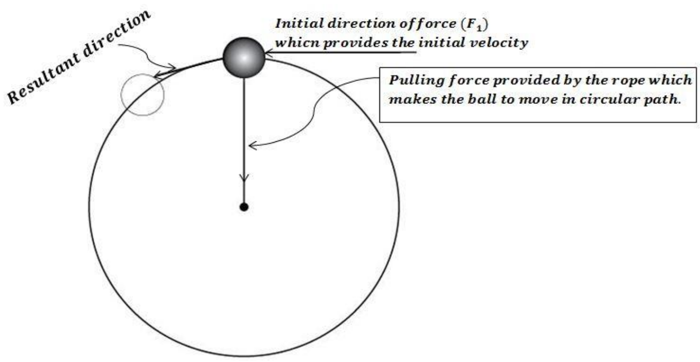


Figure 5: Resultant Motion of a body when attached by a rope is circular motion.

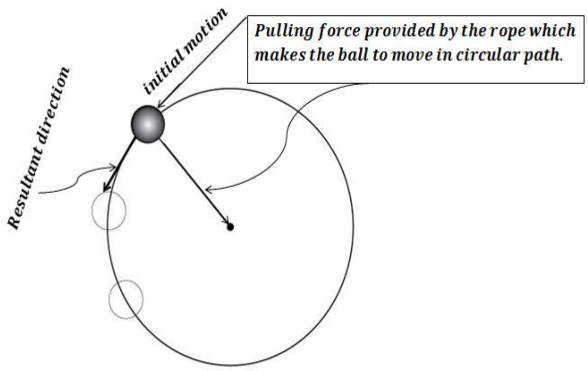
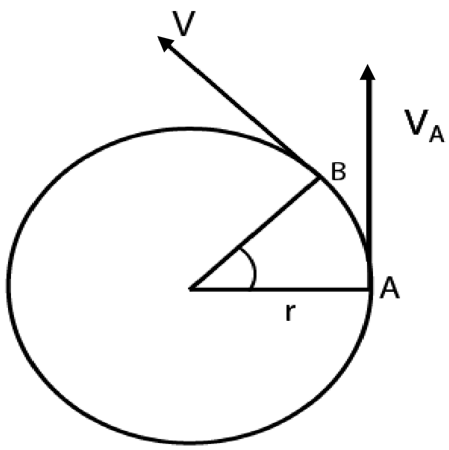


Figure 6:Resultant Motion of a body when attached by a rope is circular motion.



Any motion in a circular path represents accelerated motion, and requires a force directed toward the center of the circular path. This force is called the centripetal force which means "center seeking" force. In simple terms, centripetal force is defined as a force which keeps a body moving with a uniform speed along a circular path and is directed along the radius towards the center. This force has the magnitude:

$$F_{centripetal} = m \times a = m \times {v^2}/{r}$$

Where, **a**= centripetal acceleration

v= velocity of earth

r= radius of circle where body revolves

While swinging a ball attached in a string, it requires a centripetal force to rotate in a circular motion. The tension(force) on the string gives the required centripetal force for a ball to rotate in a circular motion. The centripetal acceleration can be derived for the case of circular motion and is found to be:

$$\boldsymbol{a} = {\boldsymbol{v}^2}/{\boldsymbol{r}}$$

1.4 Why Earth revolves round the Sun?

We all know that earth revolves round the sun. It completes one revolution in 365 days (1 year). But what is that which makes the earth revolve round the sun in an elliptical path? Obviously there is no friction in the space so that motion of the earth slows down. According to Newton's first law, every moving body continuous to be in a straight line until it is acted upon by an external force. But why does earth change its direction continuously in a circular path?

Well there is also another force in the universe called as Gravitational force. This force is due to the mass of body (there are theories explaining about this) and this force is attractive in nature and it is a small force as compared to the electrostatic force. So two bodies always attract each other but we don't see in our daily life because this force is very small for small mass and can be neglected. But for huge heavenly bodies like earth and sun this force's effect is seen properly. The sun has huge mass as compared to the earth, and hence the sun pulls the earth more towards its centre with this force. We know if a uniformly moving body is acted upon by external force it changes its velocity or acceleration or both. And in this case the force is perpendicular to the motion of earth; so every

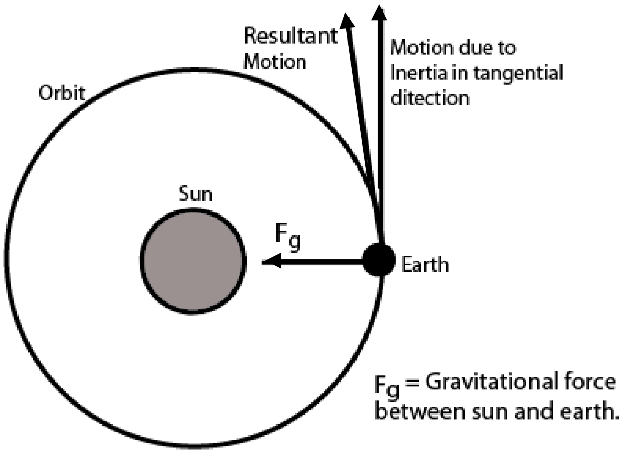


Fig: Demonstration of the revolution of earth around sun time earth moves it changes its direction and hence as a result we see that earth is revolving around the **sun being in the center** of the circular path made by the earth. Here the gravitational force is responsible for revolving earth around the sun and it acts as a centripetal force. Centripetal force is that type of force which makes anybody moves in a circular path and this force always point towards the centre. In our case, centripetal force is given by gravitational force between earth and the sun. So, due to these two effect i.e one due to original motion of earth (the earth has its original motion from the evolution of our solar system) and another due to the centripetal force, the earth is bound to revolve around the huge heavenly body ,Sun.

Now, what if there was no Sun? Would the earth be able to make a revolution? Well in that case the earth would travel in a straight line according to the Newton's first law of motion and it would never stop. So, it is sun's gravity that alters earth's motion.