Kinds of Inertia

There are three types of inertia:
1. Inertia of rest: The ability of a body to resist any change in its state of rest. i.e. body at rest.
2. Inertia of motion: The ability of a body to resist any change in its state of motion. i.e. moving body with uniform speed.
3. Inertia of rotation: The ability of a body to resist any change in its state of rotation.i.e. rotating body with uniform speed.

First law of motion

A body continues to be in its state of rest or in uniform motion in a straight line unless an external unbalanced force is applied on it.

Newton's first law in practical scenarios

Some applications of Newton's first law in real life scenarios are:
1. A suitcase kept in the train remains in rest w.r.t the train unless brakes are applied or train gains speed.
2. Passengers in the bus fall forward when brakes are applied.

Frame of reference

Inertial frame of reference are frames of reference which have zero acceleration. Force on a body in an inertial frame of reference due to the reference frame is zero.

Non-Inertial frame of reference are frames of reference which have non-zero acceleration. Force on a body in an inertial frame of reference due to the reference frame is non-zero and opposite to the direction of acceleration of the frame of reference.

Linear Momentum

Linear momentum is defined as a product of mass of an object and its velocity. It's a vector quantity. Any change in mass or the velocity of the system causes change in linear momentum.

Second Law of Motion

The rate of change of momentum of a body is directly proportional to the force applied on it and this change in momentum takes place in the direction of the applied force.

Applications of third law of motion

Newton's third law states that for every action there is an equal and opposite reaction. As you stand on the ground, your body push on the earth with a force, and the earth reacts on your body with the same force in opposite direction. This is an example of Newton's third law.

Identify action-reaction pairs

Action and reaction forces on a body never balance out. The reason being action and reaction exist in pair and are always equal in magnitude and opposite in direction. But they act on different bodies, hence they cannot balance each other.

For example, in rocket propulsion rocket moves up after getting reaction force from the ejecting jet.

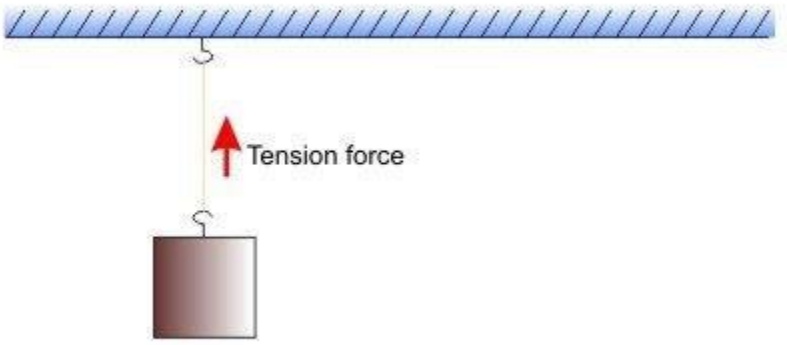
Normal Reaction

When any two surfaces are in contact, a contact force is exerted between the surfaces. Normal reaction is the component of the contact force normal to the contact surface.
For example, for a block placed on ground, the ground exerts an upward normal reaction force on the block.

Normal reaction forces in real life

Some examples of normal reaction forces in real life are:
1. When standing on the ground, we feel a normal reaction equal to the weight due to the ground. This principle is used to measure the weight of a body.
2. A boy pushing a wall feels a normal reaction force due to the wall equal to the force applied on the wall.

Tension Force



Tension force is the force transmitted through a string, rope, cable or wire when it is tightly pulled by forces acting from opposite ends.
Example: In the given figure, the string applies a tension force on the block.

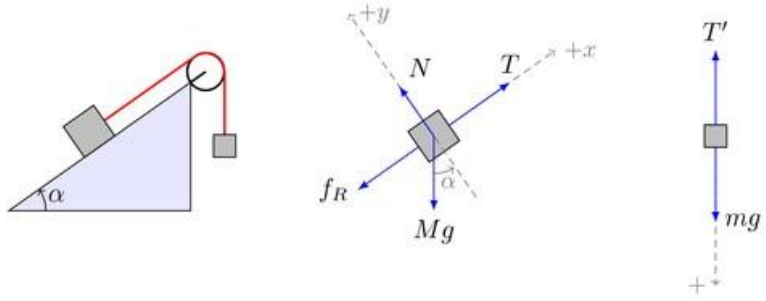
Massless string

A string having negligible mass compared to that of the object connected to it is called a massless string. Tension in a massless string is constant and always directed away from the body attached to it i.e. it is a pull force.

Tension in a string around a massless pulley

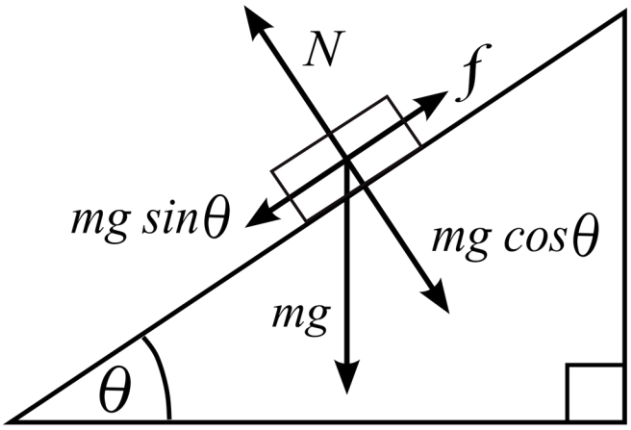
Tension in the string around the pulley spreads uniformly around it.
Both arms of the string around the pulley bears same tension.
$T_1=T_2=T$
Under Ideal conditions rotation of pulley is ignored.

Definition of a System

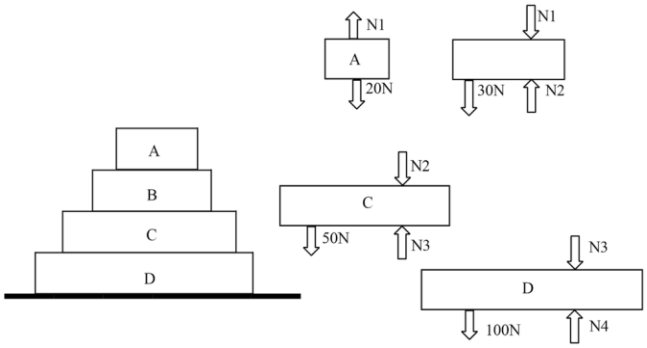


A set of things working together as parts of a mechanism or an interconnecting network. In order to study motion for a particular set of objects system is defined and different physical quantities like momentum, energy etc are calculated.

FBD for a single object with multiple forces acting on it



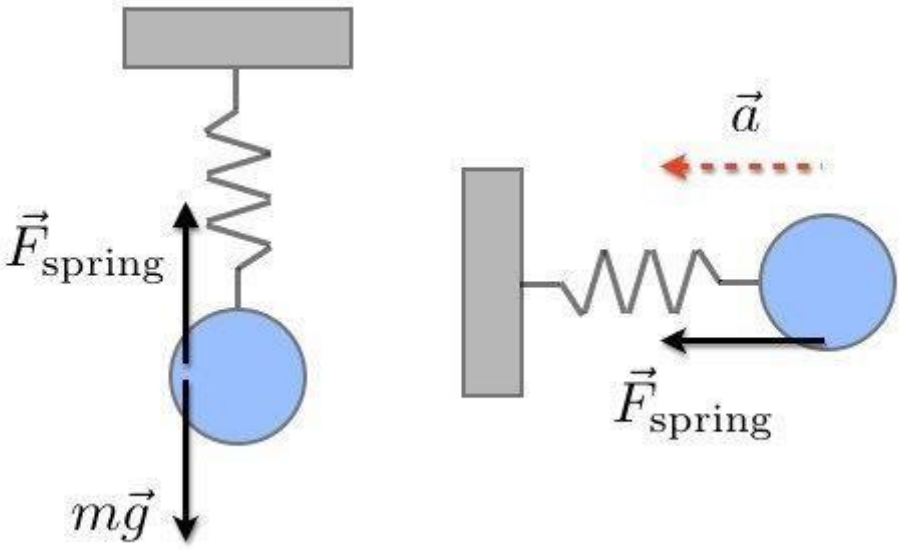
Problems Involving Multiple Blocks



Four rectangular blocks A, B, C and D have masses 2 kg, 3 kg, 5 kg and 10 kg respectively. They are placed on a horizontal surface one over the other with A at the top and D at the bottom

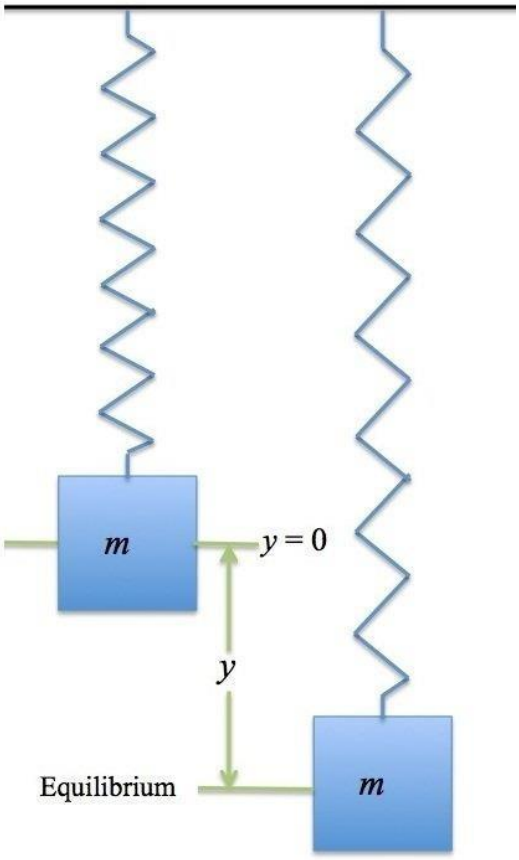
in an order. The normal reaction force between C and D will be given by: (take g=10m/s^2)
Forces are resolved as shown in figure .
N_1=20N
N_2=50N
N_3=100
N_4=200
So the Normal force between C and D is N_3=100N

Spring Force



Spring force is the force exerted by a compressed or stretched spring on the object attached to it.
If an object compresses a spring, the spring exerts a pushing force on it.
If an object stretches a spring, the spring exerts a pulling force on it.
Spring force always acts opposite to the direction of compression or stretching.

Force due to stretched massless spring

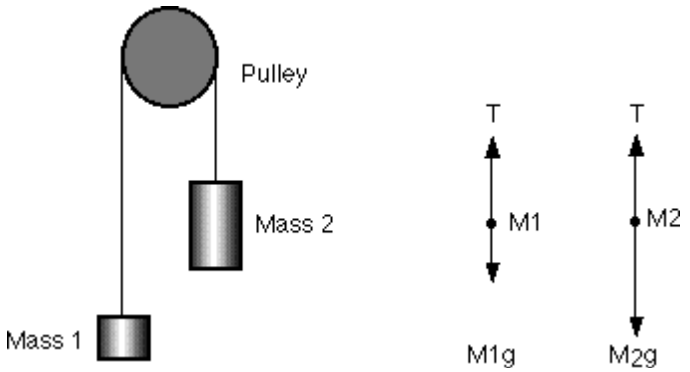


Problem:
Find force due to stretched spring for the system shown in the figure.
take, Mass of block m = 20 kg and g = 10 ms^2

Solution:

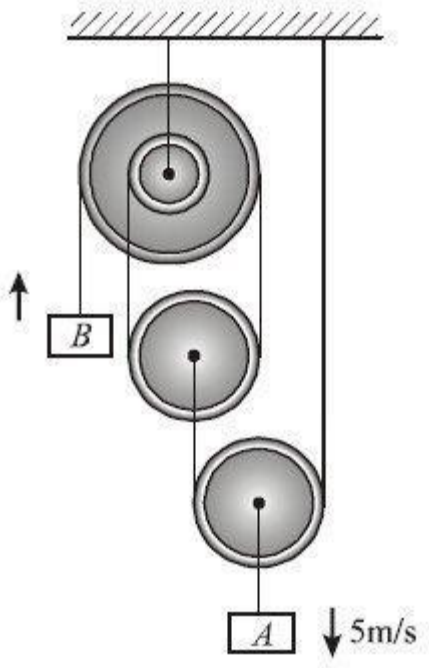
When spring stretched by length 'y' at equilibrium
Force due to stretched spring = weight of block
=Mg=20×10=200 N

Atwood Machine



Atwood machine with string around it and acting force on the string.

Pulley-mass system with moving pulleys



In the pulley system shown in figure, at an instant if block A is going down at 5 m/s, block B moves with 5x m/s. Then x will be:

(In step pulley the ratio of radii is 1:2)

If we analyse each system separately,

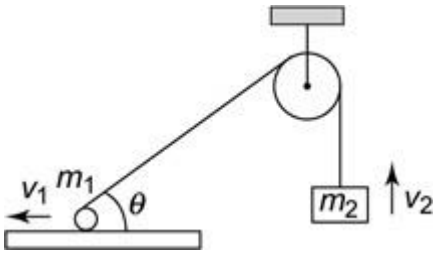
Figure shows velocities in each of the string,

Thus comparing the values we get

$V_A=8\times V_B$

Therefore x=8.

Constrained Motion



In a system of elements, free motion is restricted due to some constraints and any relative motion which arises due to these constraints is called constrained motion.
There are 3 types of constrained motion:

- Completely constrained motion
- Incompletely constrained motion
- Successfully constrained motion

Work done by string

There are two ways to find out the work done by the string:

- ***By observation on inextensible strings of constant lengths:*** In this method, we move any one block of system observe how the length of string is being shifted from one side of pulley to other side and analyze the motion of movable pulley too. In case of a moving pulley, it pulls double the length of string from either side whereas in case of a fixed pulley change in length in string on one side is compensated by change in length of string on the other side.
- ***By method of Virtual Work:*** In this method, we consider total work done by ideal string to be zero in displacement of blocks of system, (as we know ideal string is massless which can never gain or supply energy). To analyze the same we consider different displacements of the blocks and calculate work done by strings on blocks by taking scalar product of string tension to the displacement of the block and equate total work to zero which gives us the relation of displacements of all the blocks of the system which, in turn gives us the relation in velocity and accelerations.

Pseudo Force

A pseudo force is an apparent force that acts on all masses whose motion is described using a non-inertial frame of reference that is undergoing acceleration with respect to an inertial frame. (e.g. rotating reference frame).

Force changes direction of motion

When a ball hits against a wall, it bounces back in the opposite direction. So the force exerted by the wall on the ball changes its direction of motion.

Force and its unit

Force is a push or a pull acting on an object which changes or tends to change the state of the object.
For example:
Actions, like opening the door, lifting a bag, kicking a ball, pulling a drawer, pushing a box are some of the tasks we do every day. All these actions result in the change of position of an object and for that, it requires force in the form of push or pull.

S.I unit of force is newton (N) or kgm/s^2.

Force changes shape of object

When a hammer strikes a hot rod, the rod bends. The force exerted by the hammer on the rod changes the shape of the rod.

Interactive nature of force

A force can be applied if the bodies which apply the force on each other interact. The interaction may or may not involve actual physical contact between the bodies but might actually interact from a distance. For example, like charges repel as the electric fields due to the two bodies interact.

Define and explain the characteristics of electromagnetic force

The electromagnetic force is a special force that affects everything in the universe because (like gravity) it has an infinite range. It has the ability to attract and repel charges. The electromagnetic force can be generated by three types of fields known as the electrostatic field, magnetostatic field, and the electromagnetic field.

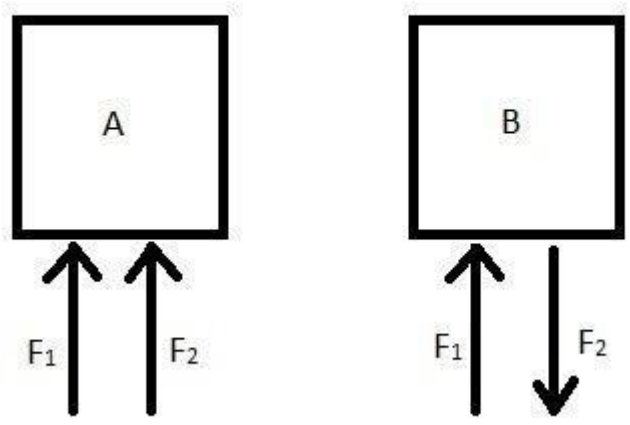
Qualitative meaning of force

Force is a quantity which changes the velocity of a body. So, a body that is sliding stops because frictional force opposes relative motion.

Units of Force

The unit of force in MKS system is newton (N)
$1N=1kg\times ms^2$
The unit of force in CGS system is dyne
1 Newton = 10^5 dynes

Addition and Subtraction of Forces



For the block A, the net force acting is F_1+F_2. The two forces are added.
For the block B, the net force acting is F_1-F_2. The two forces are subtracted.

Contact Forces

A force that can cause or change the motion of an object by touching it is called Contact Force. For example, muscular force,frictional force,spring force,tension force,air resistance force etc.

Muscular force and its examples

Muscular force is the force applied using parts of the body like arms or legs. It is force that results due to the action of muscles, and is a contact force.
All physical activity like running, lifting weight etc. requires muscular force.

Non-contact forces

A non-contact force is any force applied to an object by another body without any contact.
For example, magnetic force, gravitational force and electrostatic force.

Non-contact forces and their examples

A non-contact force is a force applied on an object by another body without being in direct contact with the object.
Examples:

- Gravitational force
- Electromagnetic force
- Strong Nuclear force
- Weak Nuclear force

Magnetic force and its examples

Moving charges and current carrying conductors create magnetic fields. Also magnets themselves have magnetic fields. When you keep two magnets close together a force is exerted between them which is a magnetic force. Iron filings placed around a magnet move because a magnetic force acts on them.

Difference between Contact and Non-Contact force

S.No.	Contact Force	Non-Contact Force
1	It acts when objects are in physical contact.Contact may be continuous or impulsive.	In acts when there is no physical contact in objects.
2	Muscular force,frictional force,spring force,normal force,tension force are few examples.	Gravitational force,electrostatic force,magnetic force and electrochemical force are few examples.

Force during collision

In a car accident, the metal body of the car gets dented. The force acting on the car during the accident changes the shape of the car.

Force can change the direction of an object

A side wind can change the direction of a boat sailing in a sea.

Force can change the speed of an object

Blowing wind or wind storm can change the speed of moving car.

Balanced and Unbalanced Forces

Balanced force:Forces acting on an object which does not change the state of rest or of uniform motion of it are called balanced forces.

Unbalanced force:The resultant of two opposite forces acts on an object and brings it in motion. These opposite forces are called unbalanced forces.

Balanced and unbalanced forces

When an object is in equilibrium, that is, it is not moving with changing speed, the net force acting on it is balanced.
For example, when an apple hangs from a tree, the weight of the apple is balanced by the force exerted by the branch on the apple.
When an object is moving with changing speed, the net force on it is unbalanced.
For example, when an apple falls from the tree an unbalanced force equal to its weight is acting on the apple.

Inertia

If the net external force is zero, a body at rest continues to remain at rest and a body in motion continues to move with a uniform velocity. This property of the body is called inertia (i.e. resistance to change).

Inertia and Mass

The inability of a body to change its state of rest or of uniform motion by itself is called inertia. Inertia of a body depends mainly upon its mass. If we kick a football, it flies away.But if we kick a stone of the same size with equal force, it hardly moves. Instead, we may injury our foot. A force, that is just enough to cause a small carriage to pick up a large velocity, will produce a negligible change in the motion of a train. We say that the train has more inertia than the carriage.

Clearly, more massive objects offer larger inertia. The inertia of an object is measured by its mass.