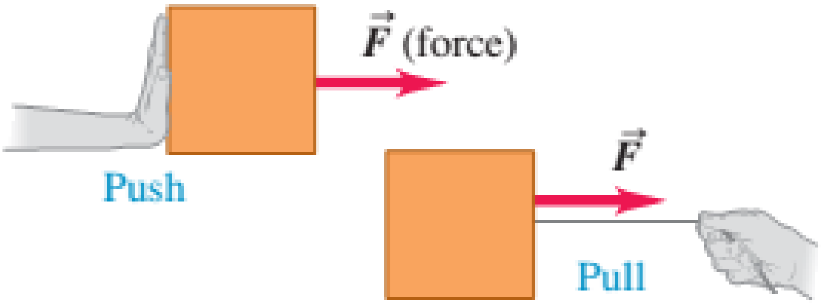
LECTURE 4

BOOK CHAPTER 5
(Force and Motion-I)

Force:



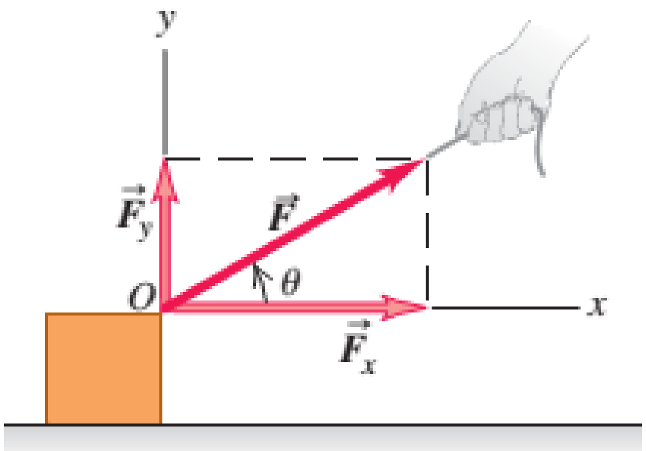
- ❑ A force is a push or a pull.
- ❑ A force is an interaction between two obj
- ❑ A force is a vector quantity, with magnitu

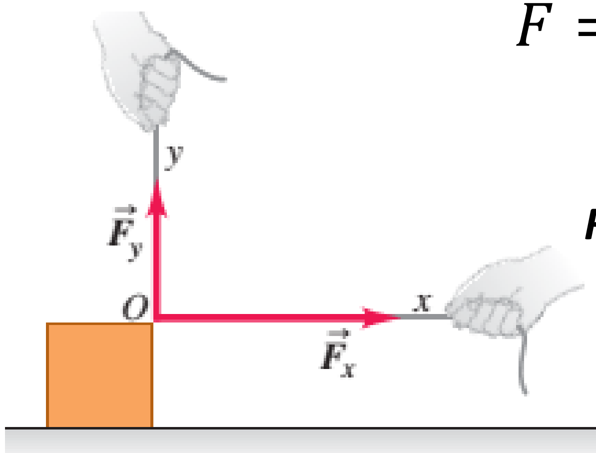
Unit of force:
SI unit: Newton (N); CGS unit: dyne; British unit: poundal(pdl)=pound-force(lbf)

MKS: F = ma=kg-m/s2=N; CGS: F = ma=gm-cm/s2=dyne;
FPS: F = ma=lb-ft/s2= poundal(pdl); pound=unit of mass=lb; 1 slug=32 lb

If two or more forces act on a body, we find the **net force** (or **resultant force**) by adding them as vectors.

$$\vec{F} = F_x\hat{\imath} + F_y\hat{\jmath}$$





Reference: university Physics

The force , which acts at an angle from the *x*-axis, may be replaced by its rectangular component vectors $\vec{F}_x$ and $\vec{F}_y$. $Here\ F_x = Fcos\theta\ \ and\ \ F_y = Fsin\theta$.

Some Particular Forces:

The Gravitational Force:

A **gravitational force** on a body is a pull by another body. In most situations, the other body is Earth or some other astronomical body. For Earth, the force is directed down toward the ground, which is assumed to be an inertial frame.

With that assumption, the magnitude of $\vec{F}_g$ is

$$F_g = mg$$

where *m* is the body's mass and *g* is the magnitude of the free-fall acceleration.

Normal Force:

A **normal force** $\vec{F}_N$ is the force on a body from a surface against which the body presses. The normal force is always perpendicular to the surface.

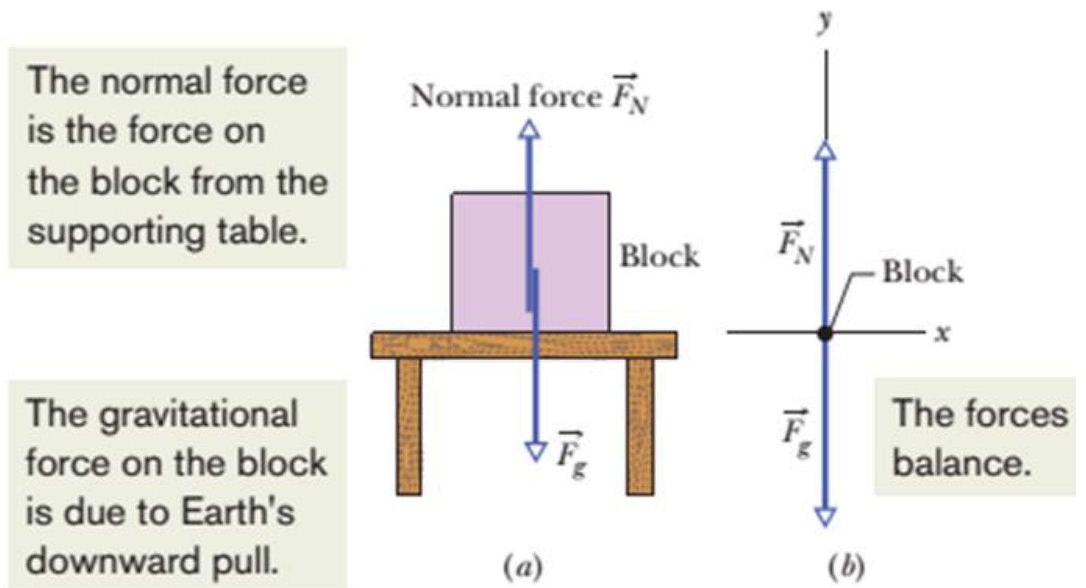


Figure (*a*) A block resting on a table experiences a normal force perpendicular to the tabletop. (*b*) The free-body diagram for the block.

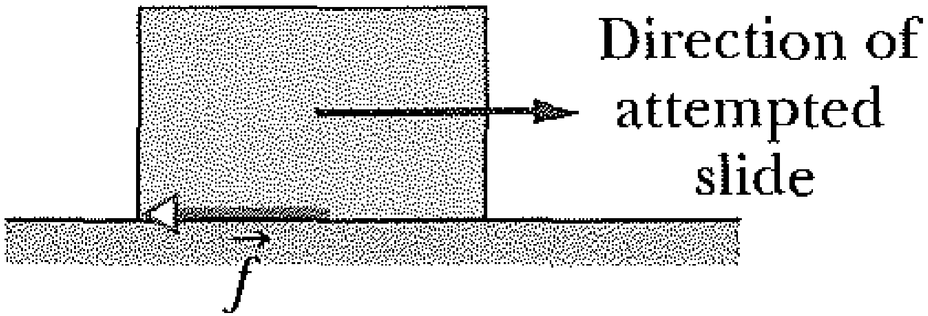
Weight:

The weight W of a body is equal to the magnitude F_g of the gravitational force on the body.

That is, $W = F_g = mg$

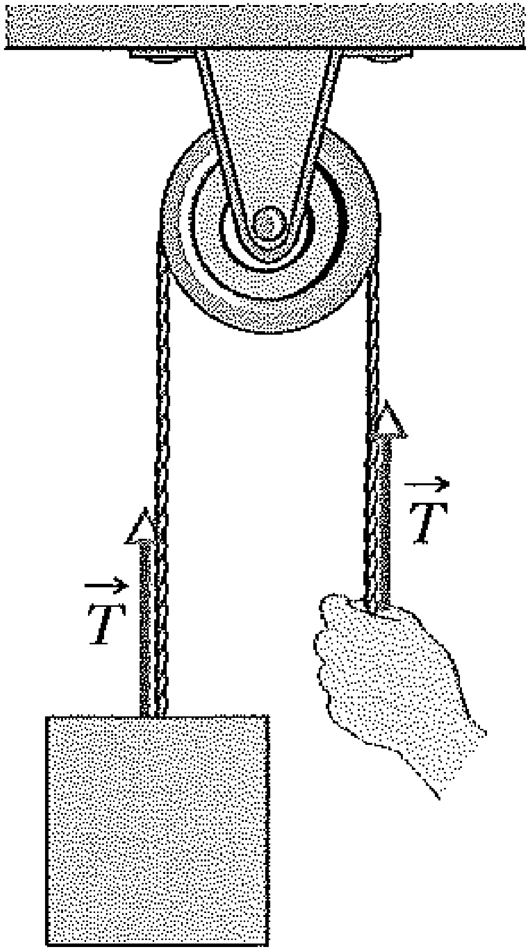
Frictional force:

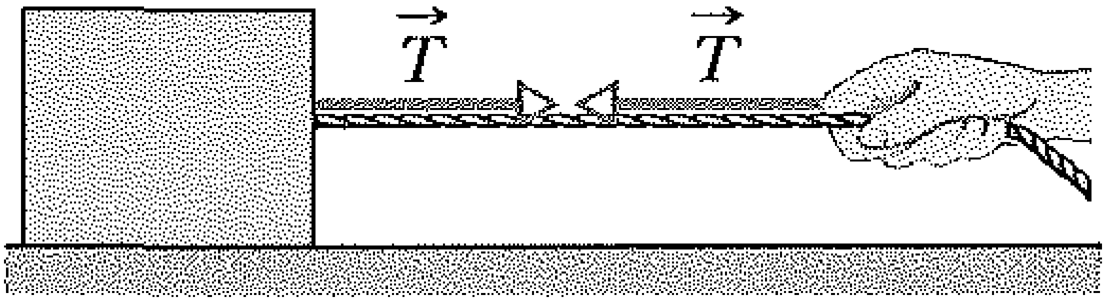
A **frictional force** is the force on a body when the body slides or attempts to slide along a surface. The force is always parallel to the surface and directed so as to oppose the sliding. On a *frictionless surface,* the frictional force is negligible.



Tension:

When a cord (or a rope, cable, or other such object) is attached to a body and pulled taut, the cord pulls on the body with a force directed away from the point of attachment to the body and along the cord (as shown in the adjacent figure). The force is often called a *tension force.* For a *massless* cord (a cord with negligible mass), the pulls at both ends of the cord have the same magnitude *T*, even if the cord runs around a *massless, frictionless pulley* (a pulley with negligible mass and negligible friction on its axle to oppose its rotation).





Newtonian Mechanics:

The relation between a force and the acceleration it causes was first understood by Isaac Newton (1642 –1727) .The study of that relation, as Newton presented it, is called *Newtonian mechanics.* We shall focus on its three primary laws of motion.

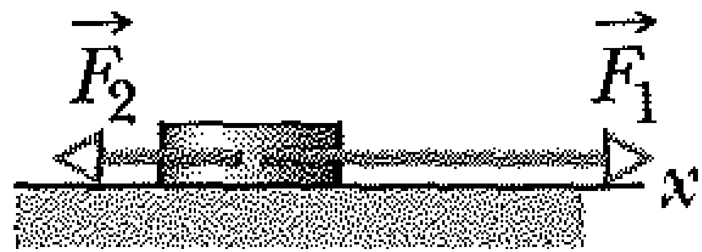
Newton's First Law:

If there is no net force on a body, the body remains at rest if it is initially at rest or moves in a straight line at constant speed if it is in motion.

OR

If no *net* force acts on a body ($\vec{F}_{net} = 0$), the body's velocity cannot change; that is, the body cannot accelerate.

Newton's Second Law:



The net force($\vec{F}_{net}$) on a body is equal to the product of the body's mass (m) and its acceleration ($\vec{a}$).

In vector equation form,

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

For a specific case along x-axis,

$$F_{net,x} = ma_x$$

$$F_1 - F_2 = ma_x$$

Units in Newton's Second Law

System	Force	Mass	Acceleration
SI	newton (N)	kilogram (kg)	m/s^2
CGS[a]	dyne	gram (g)	cm/s^2
British[b]	pound (lb)	slug	ft/s^2

[a] $1 \text{ dyne} = 1 \text{ g} \cdot \text{cm/s}^2$.

[b] $1 \text{ lb} = 1 \text{ slug} \cdot \text{ft/s}^2$.

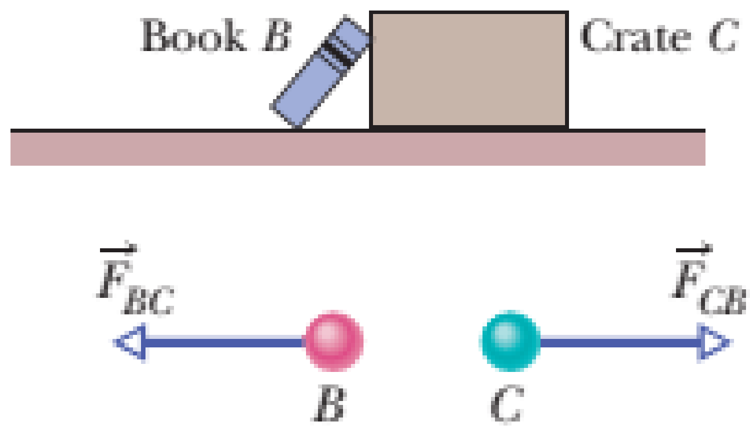
Newton's Third Law:

When two bodies interact, the forces on the bodies from each other are always equal in magnitude and opposite in direction.

For the book and crate, we can write this law as the vector relation

$$\vec{F}_{BC} = -\vec{F}_{CB}$$

(equal magnitudes and opposite directions)

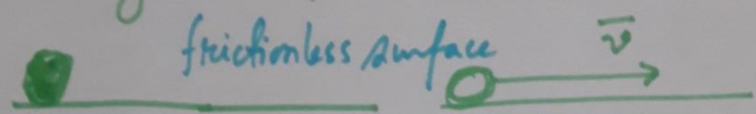


The force on B due to C has the same magnitude as the force on C due to B.

Newton's laws of motion:

Newton's first law:

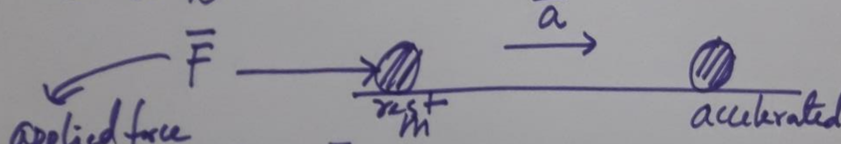
If no force acts on a body, the body's velocity cannot change; that is, the body cannot accelerate.



ball is at rest if
$\bar{F}_a = 0$

ball is moving with a constant velocity if
$\bar{F}_a = 0$

2nd law:

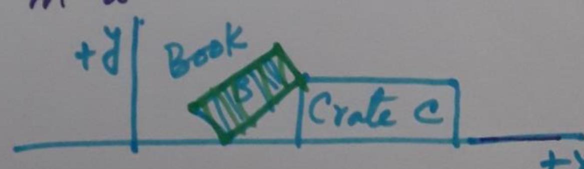


$\bar{a} \propto \bar{F}$

$\bar{F} = m\bar{a}$

$\sum \bar{F}_{net} = m\bar{a}$

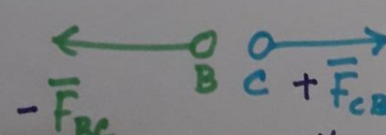
3rd law:



$\bar{F}_{BC} = -\bar{F}_{CB}$

force on B due to C

force on C due to B



forces are in opposite direction.

Free-body diagram for an object:

A **free-body diagram** is a stripped-down diagram in which only *one* body is considered. That body is represented by either a sketch or a dot. The external forces on the body are drawn (as shown in figure 2), and a coordinate system is superimposed, oriented so as to simplify the solution.

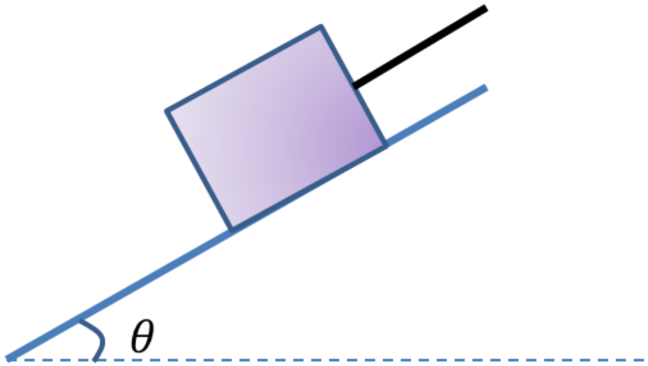


Fig.1 A box is pulled up a plane by a cord.

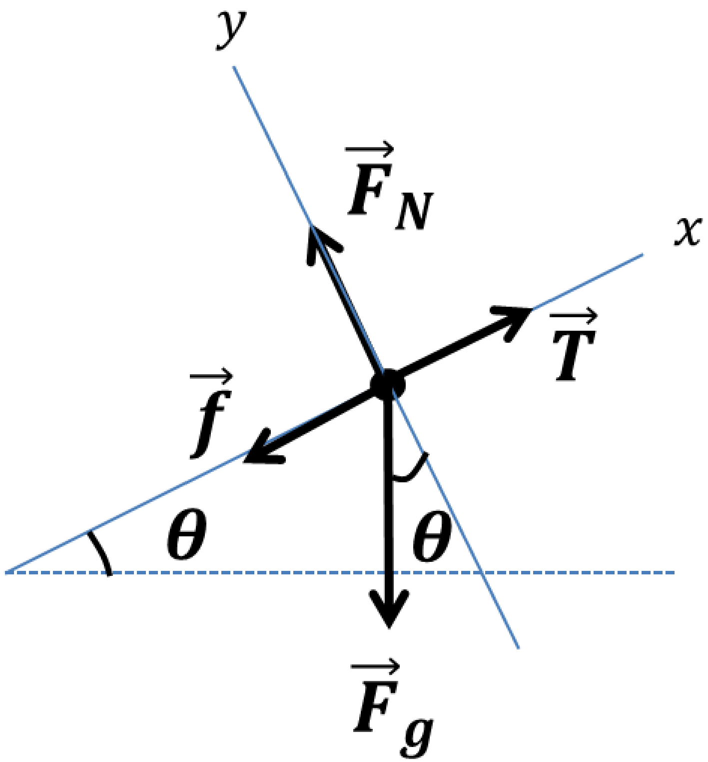
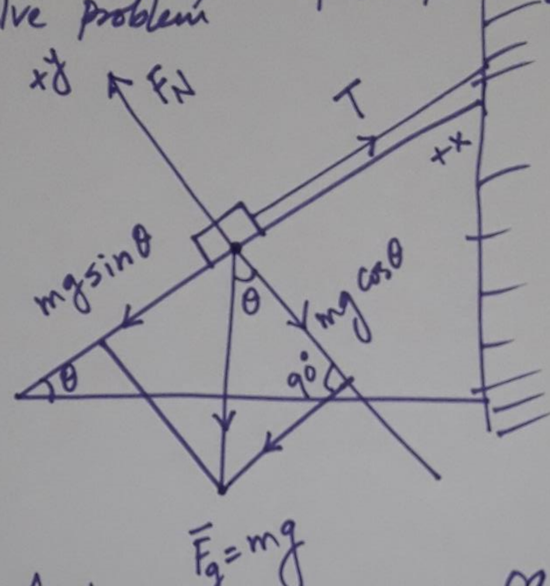


Fig.2 Four forces acting on the box:
The tension force ($\vec{T}$), the normal force($\vec{F}_N$), the frictional force($\vec{f}$), and the gravitational force($\vec{F}_g$).

Newton's 2nd law of motion: $\sum F = ma$
To solve problem



object does not move: $a = 0$
Newton's 2nd law of motion:
$\sum F = ma$

x-axis: $+T - mg\sin\theta = m a_x$
$= m(0)$
$= 0$

y-axis: $\sum F = ma$

$+F_N - mg\cos\theta = m a_y$
$= m(0)$
$= 0$