College Of Engineering
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Dept. of Chem. & Petrochemical Engineering
Subject : Physics
First Stage

Physics

Chapter-3 Force and Laws of Motion

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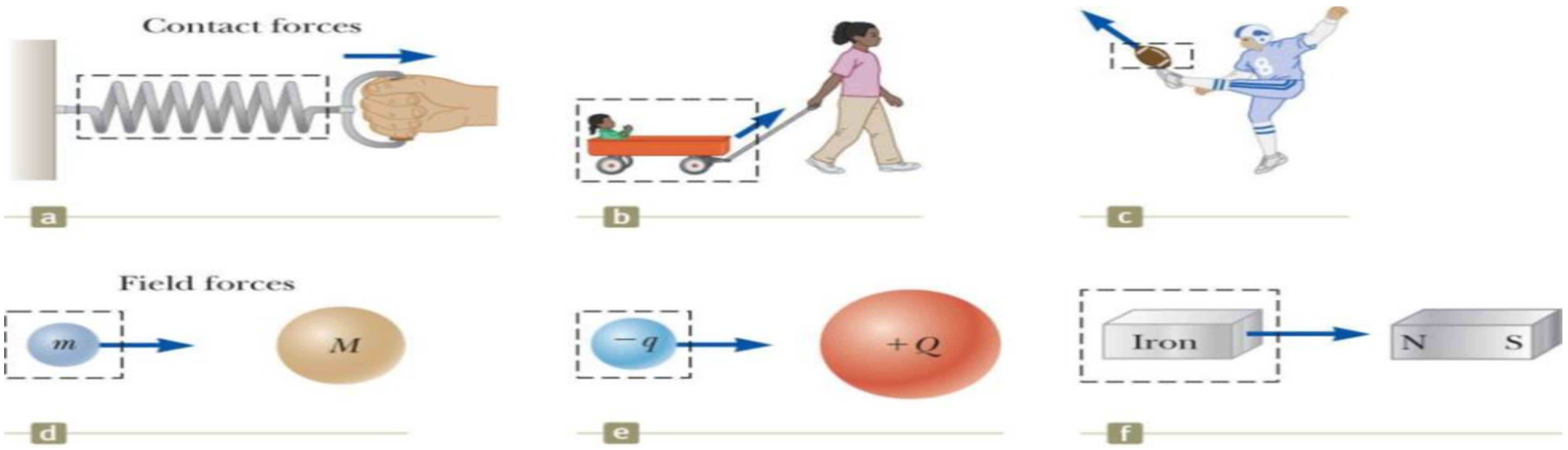
Forces

 A force is that which causes an acceleration. Formulated by Sir Isaac Newton (1642 – 1727)

Classes of Forces

Contact forces involve physical contact between two objects. Examples a, b, c Field forces act through empty space. Examples d, e, f



Fundamental Forces

Gravitational force: Between objects Electromagnetic forces: Between electric charges

Nuclear force: Between subatomic particles Weak forces: Arise in certain radioactive decay processes

Note: These are all field forces.

Newton's First Law

States that an object at rest will remain at rest and an object in motion will remain in motion with a constant velocity unless acted on by a net external force.

 Can conclude that any isolated object is either at rest or moving at a constant velocity

The First Law also allows the definition of force as that which causes a change in the motion of an object.

The tendency of an object to resist any attempt to change its velocity is called inertia.

Mass is that property of an object that specifies how much resistance an object exhibits to changes in its velocity.

Mass is a scalar quantity. The SI unit of mass is kg.

Mass and **weight** are two different quantities.

Weight is equal to the magnitude of the gravitational force exerted on the object.

- Weight will vary with location.
- m_{earth} = 3 kg; m_{moon} = 3 kg
- w_{earth} = 30 N; w_{moon} ~ 6 N

Newton's Second Law

states that the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. Force is the cause of changes in motion, as measured by the acceleration.

□Remember, an object can have motion in the absence of forces.

$$\vec{\mathbf{a}} \propto \frac{\sum \vec{\mathbf{F}}}{m} \rightarrow \sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

$\sum \vec{\mathbf{F}}$ Is the net force. May also be called the total force, resultant force

□This is the vector sum of all the forces acting on the object.

Newton's Second Law can be expressed in terms of components:

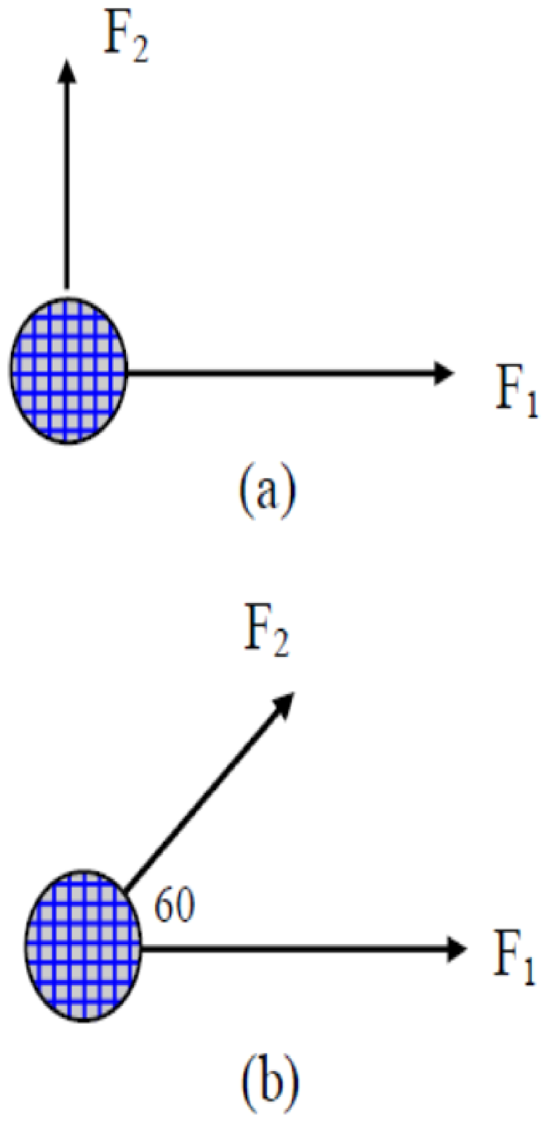
- $\Sigma F_x = m\,a_x$
- $\Sigma F_y = m\,a_y$
- $\Sigma F_z = m\,a_z$

The SI unit of force is the newton (N).

- $1\ \text{N} = 1\ \text{kg}\cdot\text{m} / \text{s}^2$

Example

Two forces, F1 and F2, act on a 5-kg mass. If F1 =20 N and F2 =15 N, find the acceleration in (a) and (b) of the Figure



Solution

(a) $\sum F = F1 + F2 = (20i + 15j)$ N

$\sum F = ma \;\therefore 20i + 15j = 5\,a$

$a = (4i + 3j)$ m/s2 or $a = 5$m/s2

(b) $F2$x = 15 cos 60 = 7.5 N

$F2$y = 15 sin 60 = 13 N

$F2 = (7.5i + 13j)$ N

$\sum F = F1 + F2 = (27.5i + 13j) = ma = 5\,a$

$a = (5.5i + 2.6j)$ m/s2 or $a = 6.08$m/s2

Gravitational Force

The gravitational force, $\vec{\mathbf{F}}_g$, is the force that the earth exerts on an object.

This force is directed toward the center of the earth.

From Newton's Second Law:

- $\vec{\mathbf{F}}_g = m\vec{\mathbf{g}}$

Its magnitude is called the weight of the object.

- Weight = $F_g = mg$
- *g*, and therefore the weight, is less at higher altitudes.
- This can be extended to other planets, but the value of g varies from planet to planet, so the object's weight will vary from planet to planet.
- The weight is a property of a *system* of items: the object and the Earth.

Note about units:

- Kilogram is **not** a unit of weight.
- 1 kg = 2.2 lb is an equivalence valid only on the Earth's surface.

concept 1

Newton's third law

Forces come in pairs
Equal in strength, opposite in direction
The forces act on different objects

equation 1

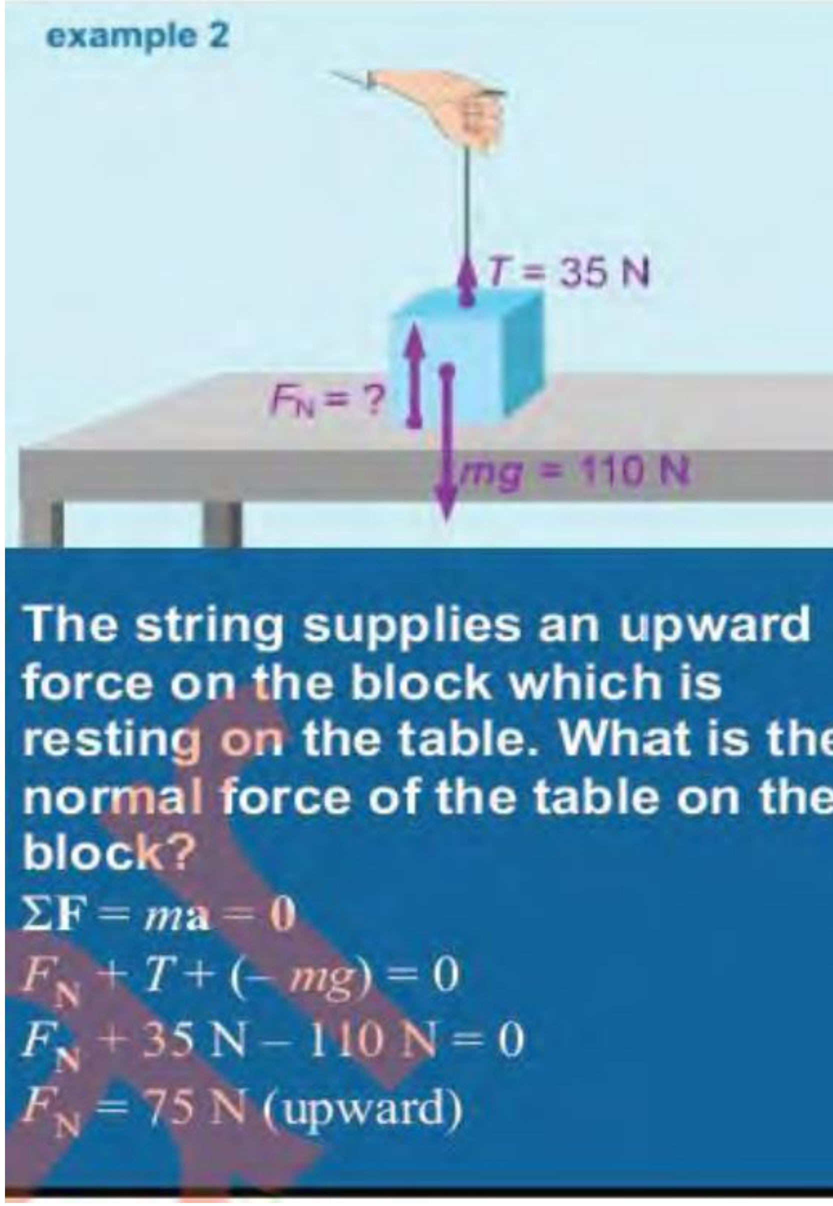
Newton's third law

$$\mathbf{F}_{ab} = -\mathbf{F}_{ba}$$

Newton's third law: "To any action there is always an opposite and equal reaction; in other words, the actions of two bodies upon each other are always equal and always opposite in direction."

Newton's third law states that forces come in pairs and that those forces are equal in magnitude and opposite in direction. When one object exerts a force on another, the second object exerts a force equal in magnitude but opposite in direction on the first.

For instance, if you push a button, it pushes back on you with the same amount of force. When someone leans on a wall, it pushes back, as shown in the illustration above.



Newton's Third Law

If two objects interact, the force $\vec{F}_{12}$ exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force $\vec{F}_{21}$ exerted by object 2 on object 1.

- $\vec{F}_{12} = -\vec{F}_{21}$
- Note on notation: $\vec{F}_{AB}$ is the force exerted *by* A *on* B.

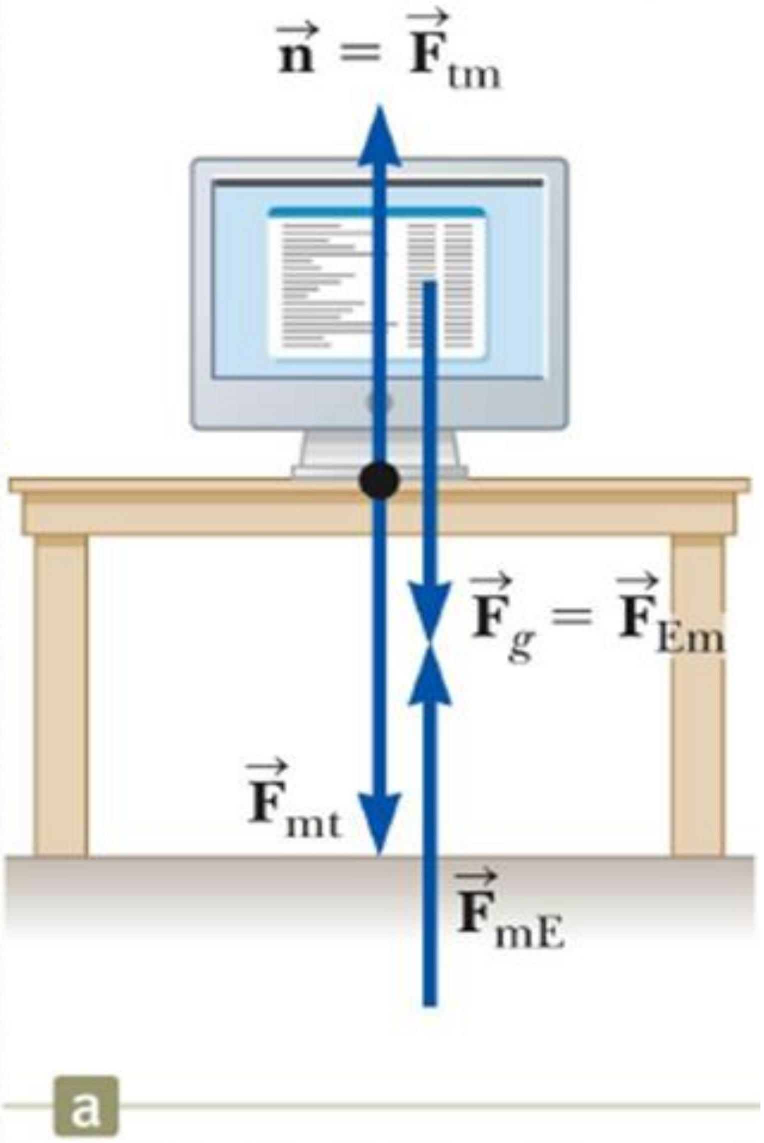
The action force is equal in magnitude to the reaction force and opposite in direction.

- One of the forces is the action force, the other is the reaction force.

The normal force (table on monitor) is the reaction of the force the monitor exerts on the table. (Figure a)

- Normal means perpendicular, in this case

The action (Earth on monitor) force is equal in magnitude and opposite in direction to the reaction force, the force the monitor exerts on the Earth.



Free Body Diagram

In a free body diagram, you want the forces acting on a particular object. (Figure b)

- Model the object as a particle

The normal force and the force of gravity are the forces that act on the monitor.

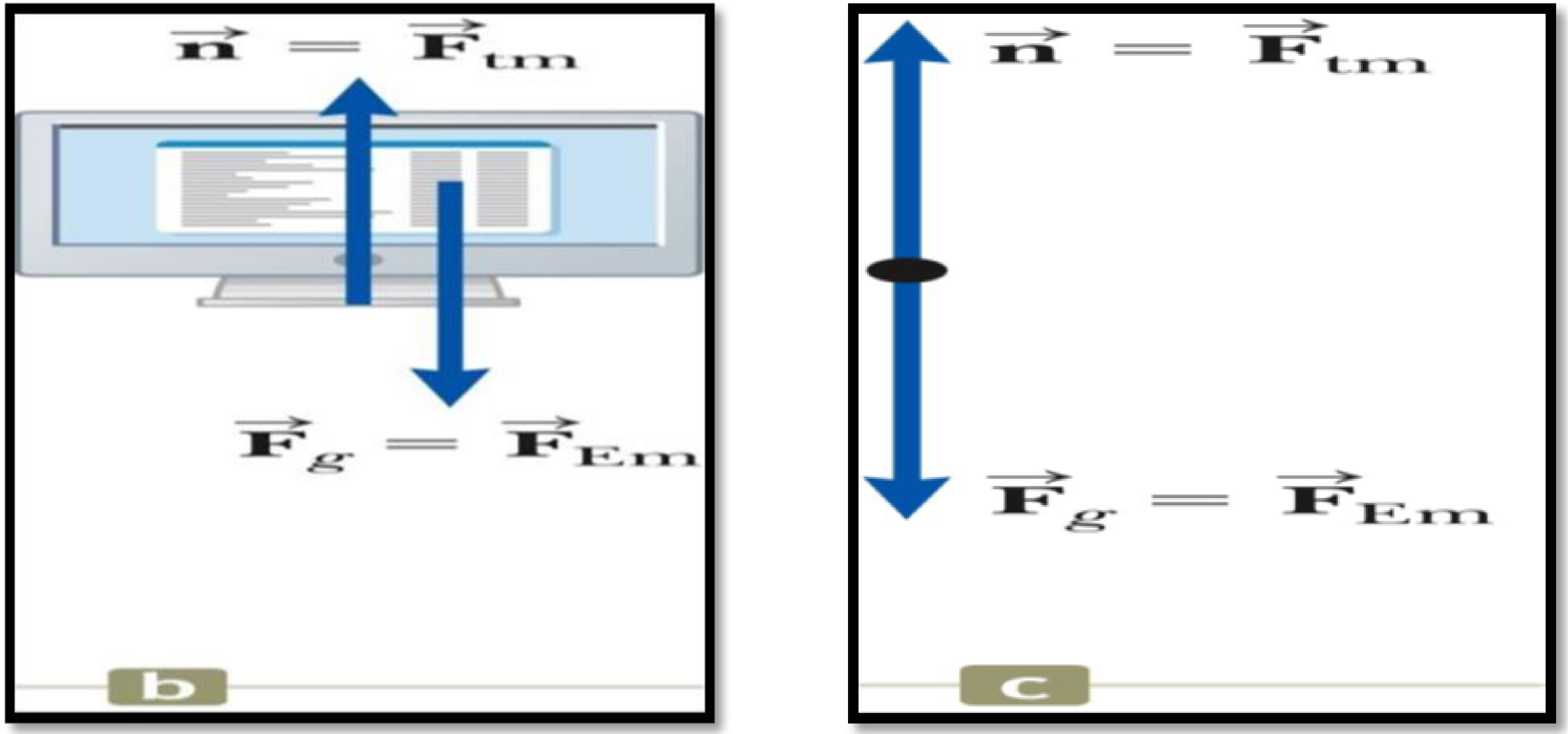
The most important step in solving problems involving Newton s Laws is to draw the free body diagram.

Be sure to include only the forces acting on the object of interest.

Include any field forces acting on the object.

Do not assume the normal force equals the weight.

The forces that act on the object are shown as being applied to the dot. The free body helps isolate only those forces acting on the object and eliminate the other forces from the analysis.



The object in Equilibrium

If the acceleration of an object is zero, the object is said to be in equilibrium.

□The model is the particle in equilibrium.

Mathematically, the net force acting on the object is zero.

$$\sum F = 0$$

Example

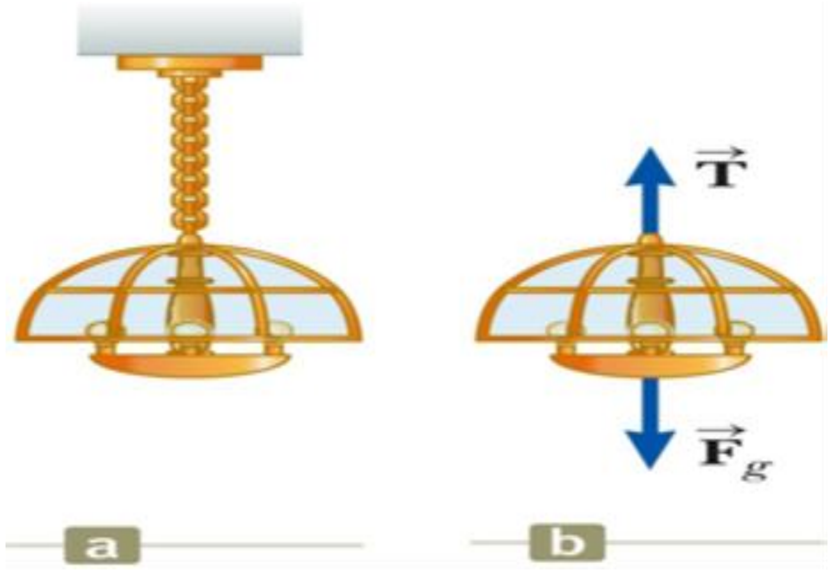
A lamp is suspended from a chain of negligible mass.

The forces acting on the lamp are:

- The downward force of gravity
- The upward tension in the chain

Applying equilibrium gives

$$\sum F_y = 0 \rightarrow T - F_g = 0 \rightarrow T = F_g$$



The Object under a Net Force, example

Forces acting on the crate:

- A tension, acting through the rope, is the magnitude of force $\vec{T}$
- The gravitational force, $\vec{F}_g$
- The normal force, $\vec{n}$, exerted by the floor

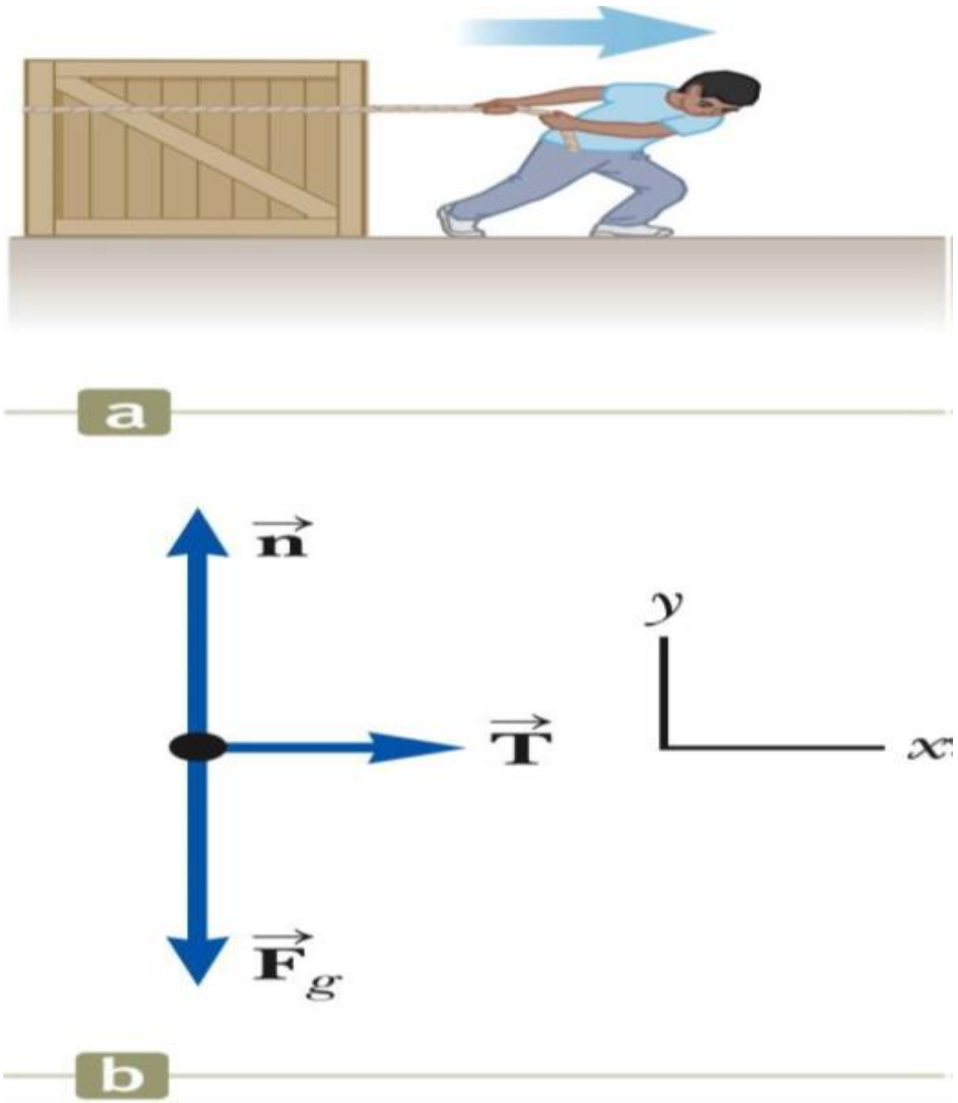
Apply Newton’s Second Law in component form:

$$\sum F_x = T = ma_x$$

$$\sum F_y = n - F_g = 0 \rightarrow n = F_g$$

Solve for the unknown(s)

If the tension is constant, then a is constant and the kinematic equations can be used to more fully describe the motion of the crate.


a
$\vec{n}$
$\vec{T}$
$\vec{F}_g$
y
x
b