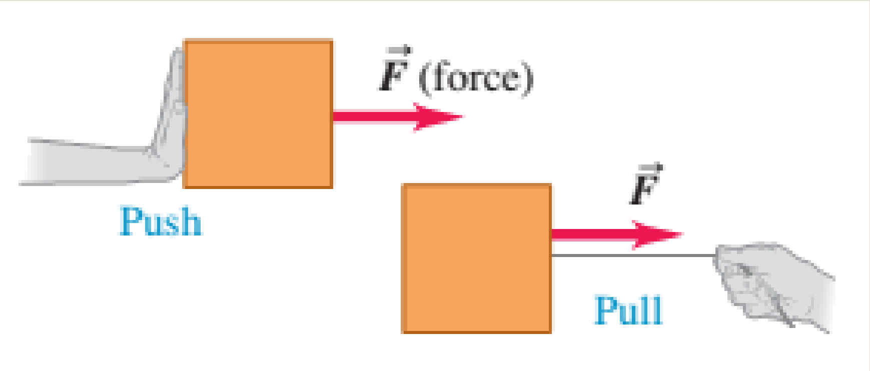
- BOOK CHAPTER 5
- (Force and Motion-I)

# LESSON 4

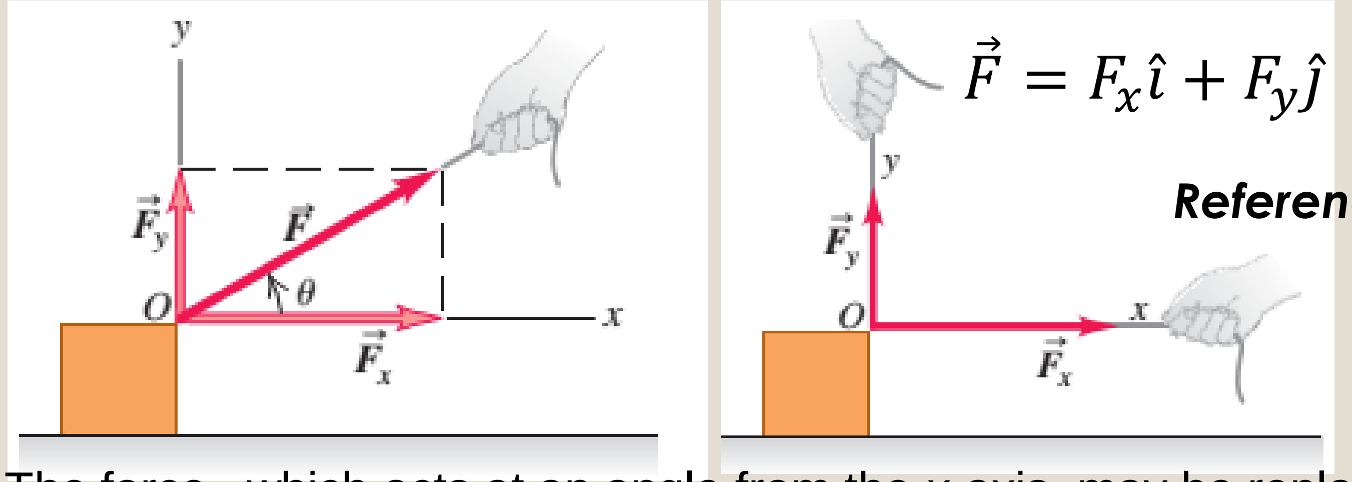
# Force and interactions:




- A force is a push or a pull.
- A force is an interaction between two objects.
- A force is a vector quantity, with magnitude and direction.

Units of force: SI unit: Newton (N); CGS unit: dyne; British unit: pound (lb)

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




***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 $\vec{F}_y$. $Here\ F_x = F cos\theta\ \ and\ \ F_y = F sin\theta$ .

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

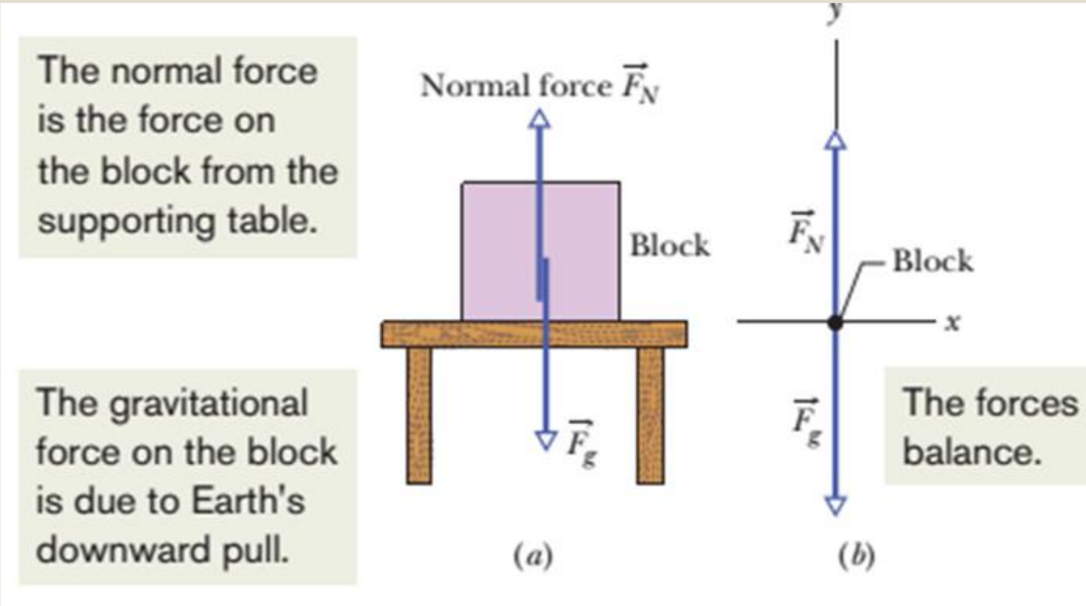



**Figure** (*a*) A block resting on a table experiences a normal force perpendicular to the tabletop. (*b*) The free-body diagram for the block.

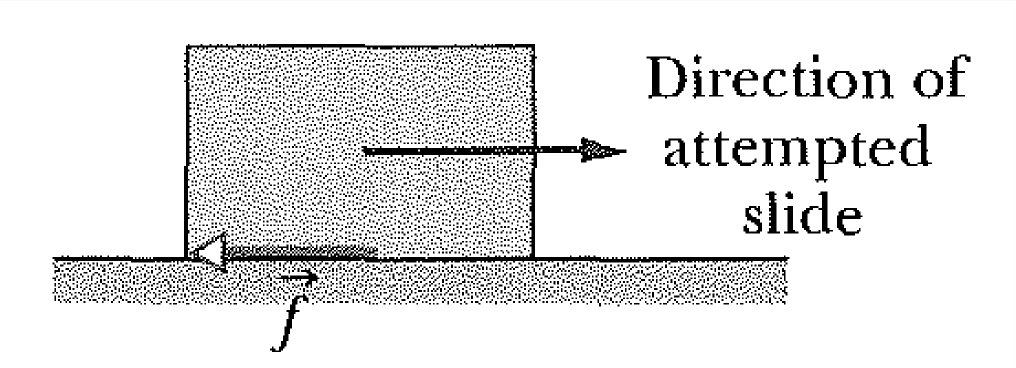
## ❑ Weight:

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

That is, $W = F_g = mg$

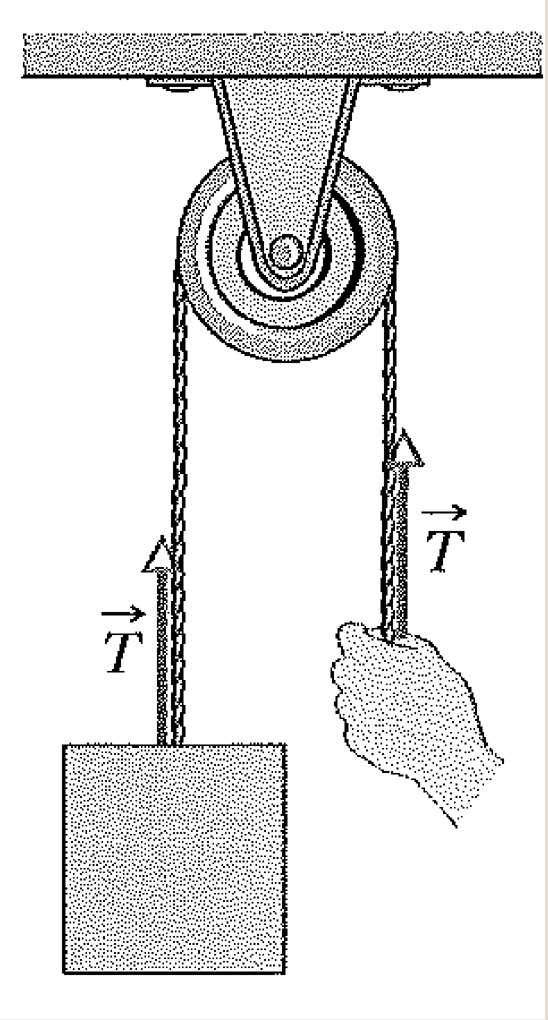
## ❑ Frictional force:

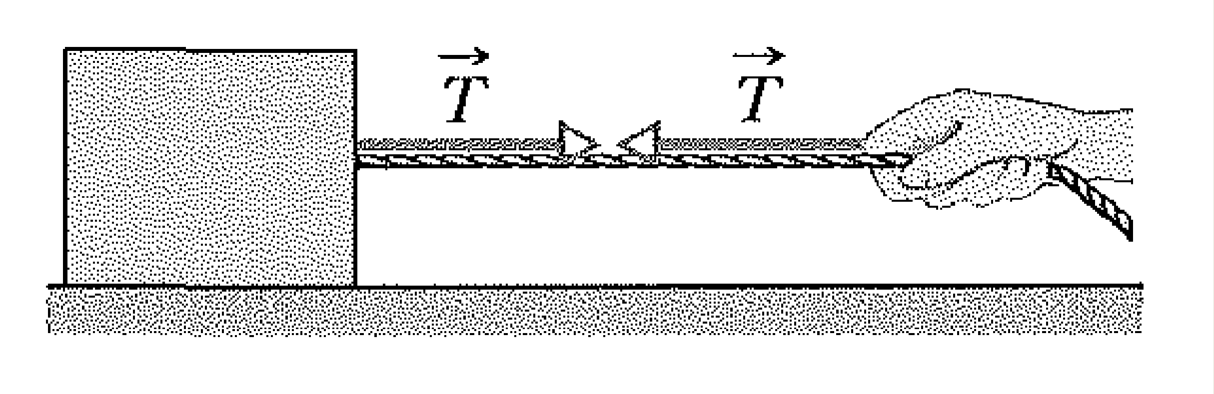
A **frictional force** is the force on a body when the body slides or attempts to slide along a surface. The force is always parallel to the surface and directed so as to oppose the sliding. On a *frictionless surface,* the frictional force is negligible.



## ❑ 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.

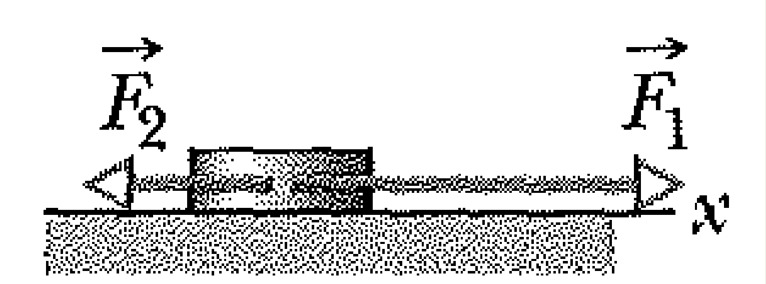
## Newton's First Law:

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,

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

$$F_1 - F_2 = ma_x$$


**4.17** The design of high-performance motorcycles depends fundamentally on Newton's second law. To maximize the forward acceleration, the designer makes the motorcycle as light as possible (that is, minimizes the mass) and uses the most powerful engine possible (thus maximizing the forward force).

**Application Blame Newton's Second Law**

This car stopped because of Newton's second law: The tree exerted an external force on the car, giving the car an acceleration that changed its velocity to zero.

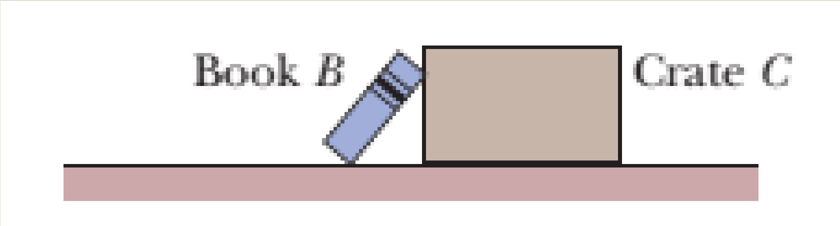
# Newton’s Third Law:

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

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

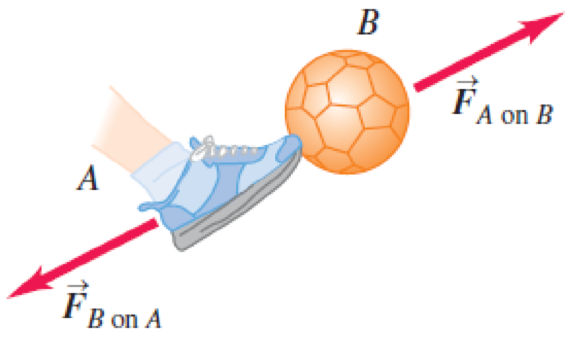
(equal magnitudes and opposite directions)





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

**4.25** If body $A$ exerts a force $\vec{F}_{A \text{ on } B}$ on body $B$, then body $B$ exerts a force $\vec{F}_{B \text{ on } A}$ on body $A$ that is equal in magnitude and opposite in direction: $\vec{F}_{A \text{ on } B} = -\vec{F}_{B \text{ on } A}$.



# 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.

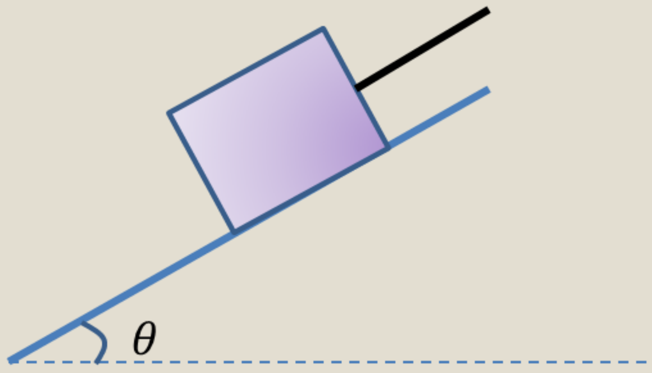



**Fig.1** A box is pulled up a plane by a cord.

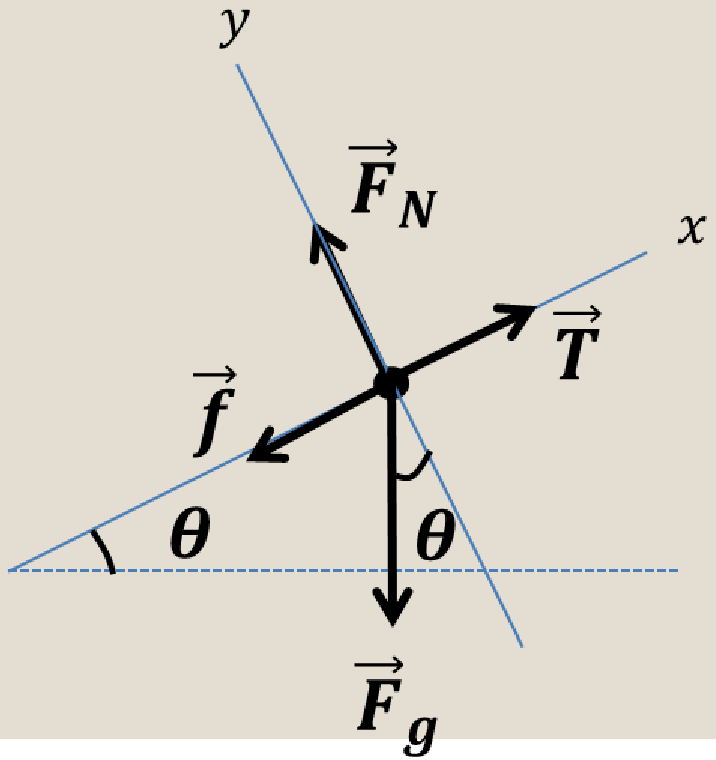
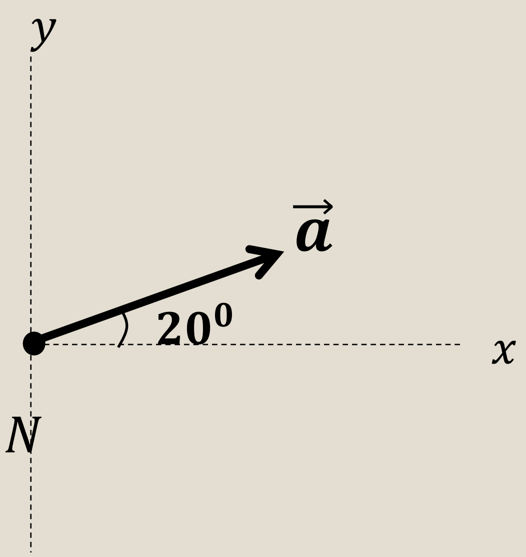



**Fig.2** Four forces acting on the box:
The tension force ($\vec{T}$), the normal force($\vec{F}_N$), the frictional force($\vec{f}$), and the gravitational force($\vec{F}_g$).

## Problem 3 (Book chapter 5):

If the 1 kg standard body has an acceleration of 2.00 m/s$^2$ at 20.0° to the positive direction of an *x* axis, what are (a) the *x* component and (b) the *y* component of the net force acting on the body, and (c) what is the net force in unit-vector notation?




**Answer:**

(a) The x component acceleration, $a_x = a\cos 20^0$

$$a_x = (2)(0.9397) = 1.879\ m/s^2$$

The x component force, $F_x = ma_x = (1)(1.879) = 1.879\ N$

(b) The y component acceleration, $a_y = a\sin 20^0$

$$a_y = (2)(0.3420) = 0.6840\ m/s^2$$

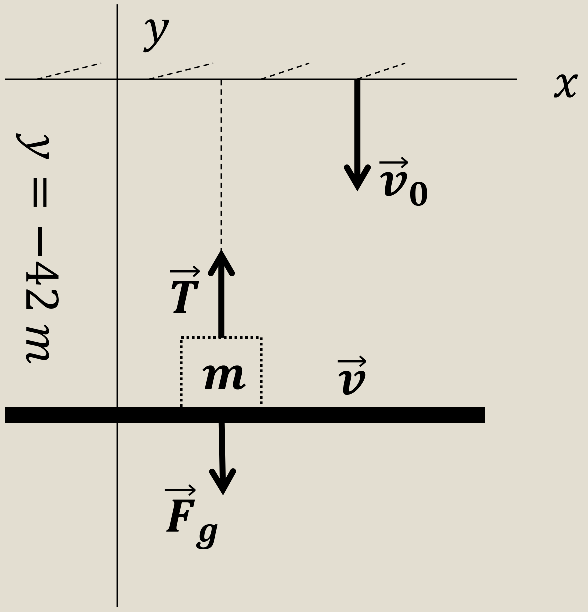
The y component force, $F_y = ma_y = (1)(0.6840) = 0.6840\ N$

(c) The resultant force (net force) in unit -vector notation,

$$\vec{F} = F_x\hat{\imath} + F_y\hat{\jmath} = 1.879\ \hat{\imath} + 0.684\ \hat{\jmath}$$

## Problem 33 (Book chapter 5):

An elevator cab and its load have a combined mass of 1600 kg. Find the tension in the supporting cable when the cab, originally moving downward at 12 *m/s*, is brought to rest with constant acceleration in a distance of 42 m.




**Answer:** We have from Newton's second law,

$$mg - T = ma$$

$$T = mg - ma = m(g - a) = 1600(9.8 - a)$$

To find $a$, we use the following formula,

$$v^2 = v_0^2 + 2ay$$

$$0 = (12)^2 + 2a(42)$$

$$0 = 144 + 84a$$

$$84a = -144$$

$$\boldsymbol{a = -1.714\ m/s^2}$$

Therefore,

$$T = 1600(9.8\ - (-1.714))$$

$$T = 1600(9.8 + 1.714)$$

$$\boldsymbol{T = 18,422\ N}$$

Here, $v_0 = 12\ m/s$

$v = 0\ m/s$

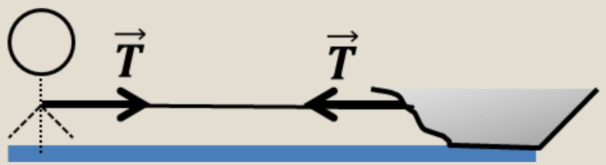
$m = 1600\ kg$

$y = 42\ m$

$T = ?$

# Problem 37 (Book chapter 5):

A 40 kg girl and an 8.4 kg sled are on the frictionless ice of a frozen lake, 15 m apart but connected by a rope of negligible mass. The girl exerts a horizontal 5.2 N force on the rope. What are the acceleration magnitudes of (a) the sled and (b) the girl? (c) How far from the girl's initial position do they meet?




**Answer:** Since the rope is of negligible mass, the pulls at both ends of the rope have the same magnitude *T.*

(a) <u>For girl</u>

From Newton's second law,

$$\boldsymbol{T = m_g a_g}$$

[where, $m_g \rightarrow mass\ of\ the\ girl$

$a_g \rightarrow acceleration\ of\ the\ girl$

and $T \rightarrow magnitude\ of\ the\ tension\ force\ along\ the\ rope$]

$$a_g = \frac{T}{m_g} = \frac{5.2}{40} = 0.13\ m/s^2$$

(b) <u>For sled</u>

From Newton's second law,

$$\boldsymbol{T = m_s a_s}$$

[where, $m_s \rightarrow mass\ of\ the$ sled

$a_s \rightarrow acceleration\ of\ the$ sled]

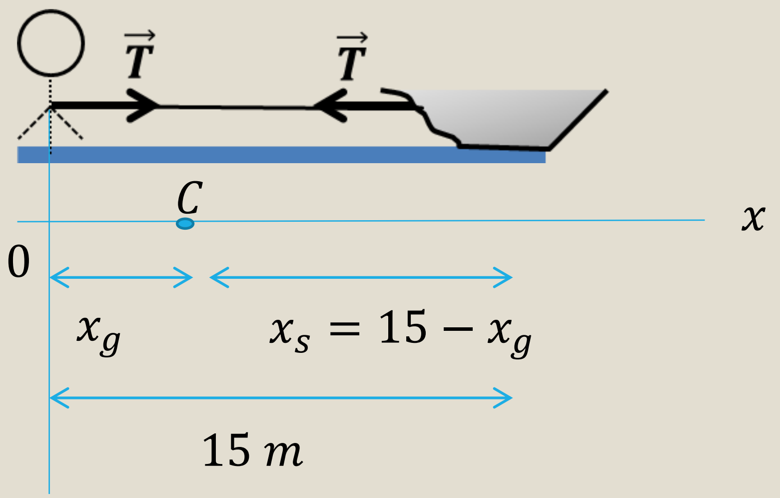
$$a_s = \frac{T}{m_s} = \frac{5.2}{8.4} = 0.619\ m/s^2$$

(c) We assume that they will meet at point C after a time t.

For girl,

$$x_g = 0 + \frac{1}{2} a_g t^2$$ [since initial velocity of girl is zero]

$$x_g = \frac{1}{2} a_g t^2$$




For sled,

$$-(15 - x_g) = -\frac{1}{2} a_s t^2$$ [since the displacement and acceleration are negative to x axis]

$$15 - \frac{1}{2} a_g t^2 = \frac{1}{2} a_s t^2$$

$$15 - \frac{0.13}{2} t^2 = \frac{0.619}{2} t^2$$

$$15 - 0.065t^2 = 0.3095t^2$$

$$0.3745t^2 = 15$$

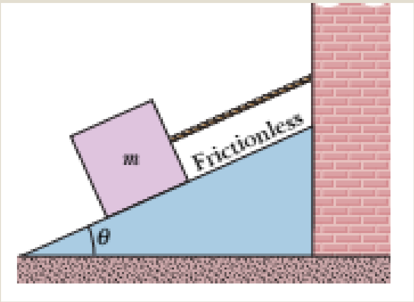
$$\boldsymbol{t = 6.329\ s}$$

**Therefore,**

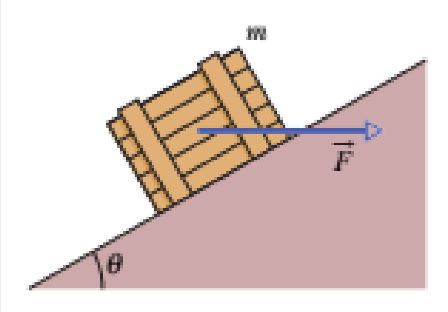
$$\boldsymbol{x_g = \frac{0.13}{2}(6.329)^2 = 2.604\ m}$$

# Let's Try .......

1. [ Chap 5 - problem 8]: Two horizontal forces act on a 2.0 kg chopping block that can slide over a frictionless kitchen counter, which lies in an xy plane. One force is $\overrightarrow{F_1} = (3\,\hat{\imath}) + (4\hat{\jmath})$ Find the acceleration of the chopping block in unit-vector notation when the other force is (a) $\overrightarrow{F_2} = (-3\,\hat{\imath}) + (-4\hat{\jmath})$ (b) $\overrightarrow{F_2} = (-3\,\hat{\imath}) + (4\hat{\jmath})$ and (c) $\overrightarrow{F_2} = (3\,\hat{\imath}) + (-4\hat{\jmath})$




2. In Figure right side shows the mass of the block be 8.5 kg and the angle θ be 30°. Find (a) the tension in the cord and (b) the normal force acting on the block. (c) If the cord is cut, find the magnitude of the resulting acceleration of the block




3. In Figure right side shows a crate of mass m = 100 kg is pushed at constant speed up a frictionless ramp ( 30.0°) by a horizontal force . What are the magnitudes of (a) and (b) the force on the crate from the ramp?

4. An elevator cab that weighs 27.8 kN moves upward. What is the tension in the cable if the cab's speed is (a) increasing at a rate of 1.22 m/s$^2$ and (b) decreasing at a rate of 1.22 m/s$^2$?

# Thank You