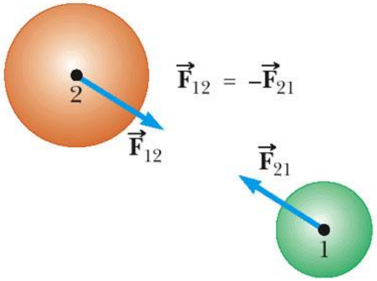
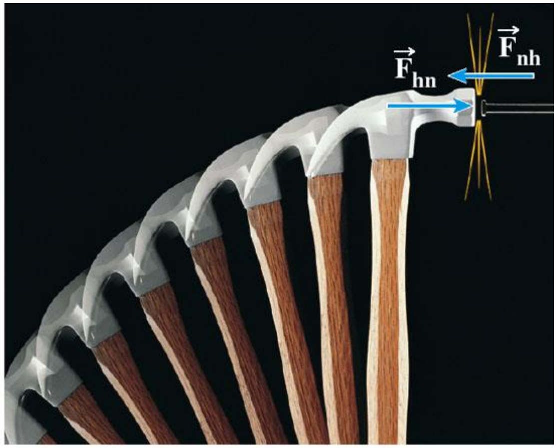
Chapter 5

Force and Motion - I





Study of relation between force and acceleration of a body:
***Newtonian Mechanics*.**

Newtonian Mechanics ***does not*** hold good for all situations.
Examples:

1. Relativistic or near-relativistic motion(相對論或近相對論運動)
2. Motion of atomic-scale particles(原子尺度粒子的運動)

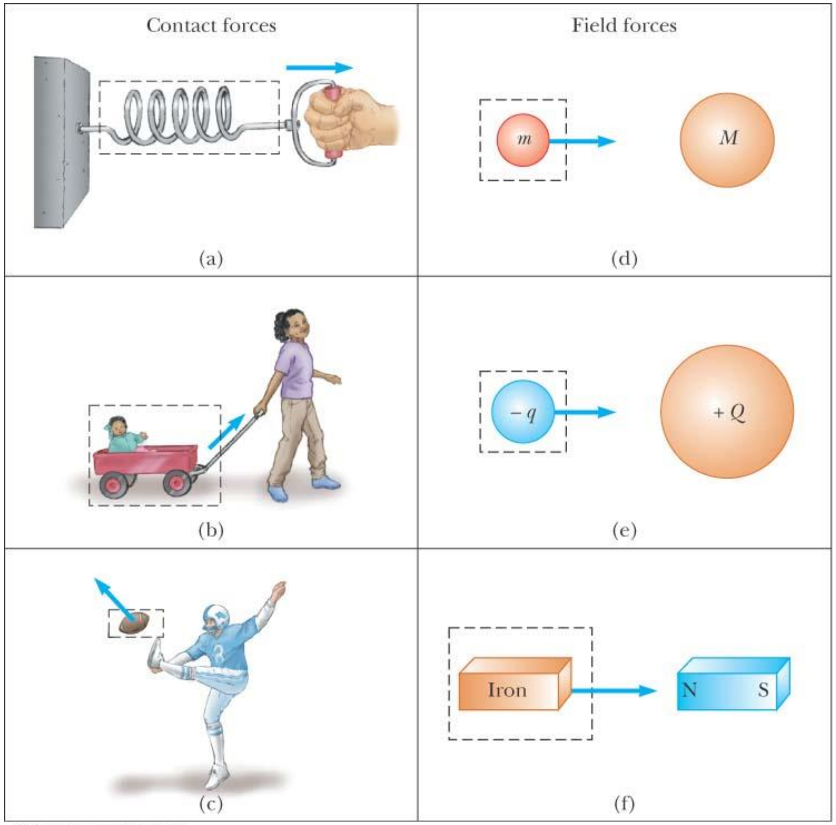
5.3 Newton's First Law

Classes of Forces力之種類:

Contact forces(接觸力): involve physical contact between two objects

Field forces act through empty space (場力、非接觸力) :

No physical contact is required



Newton's First Law:

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

➡ If the body is at rest, it stays at rest. If it is moving, it continues to move with the same velocity (same magnitude *and same direction).*

5.4 Force

- A force is measured by the acceleration it produces.

- Forces have both magnitudes and directions.

- When two or more forces act on a body, we can find their **net, or resultant force, by adding the individual forces vectorially.**

- The net force acting on a body is represented with the vector symbol $\vec{F}_{net}$

- **Newton's First Law牛頓第一定律:**

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

This is also called the *law of inertia* (又稱為慣性定律)

外力=0，靜者恆靜，動者維持等速度運動。

5.4 Force

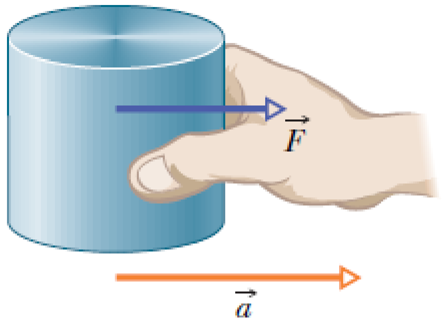


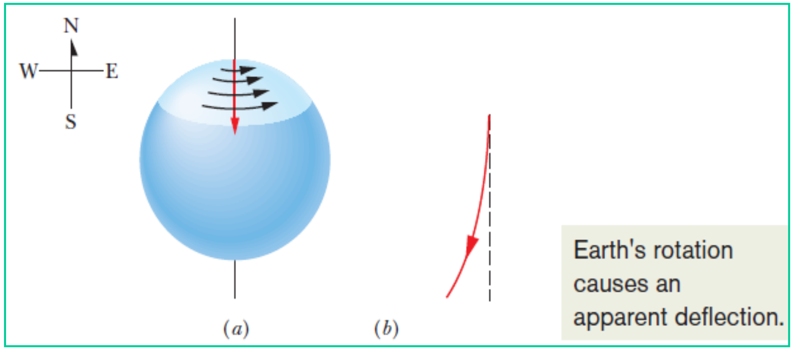
Fig. 5-1 A force $\vec{F}$ on the standard kilogram gives that body an acceleration $\vec{a}$.

The force that is exerted on a standard mass of 1 kg to produce an acceleration of 1 m/s^2 has a magnitude of 1 newton (abbreviated N)

~Unit: N, the newton; 1 N = 1 kg m/s^2

Inertial Reference Frames (慣性系統)

An inertial reference frame is one in which Newton's laws hold.



(*a) The path of a puck sliding from the north pole as seen from a stationary*
point in space. Earth rotates to the east. (*b) The path of the puck as seen from the ground.*

地球表面是為一慣性系統?

If a puck is sent sliding along a *short strip of* frictionless ice—the puck's motion obeys Newton's laws as observed from the Earth's surface.

If the puck is sent sliding along a *long ice strip extending from* the north pole, and if it is viewed from a point on the Earth's surface, the puck's path is not a simple straight line.

The apparent deflection is not caused by a force, but by the fact that we see the puck from a rotating frame. In this situation, the ground is a **noninertial frame.**

Generally, assume the ground is an inertial frame!

5.5: Mass

Mass is an *intrinsic characteristic* of a body

The mass of a body is the characteristic that relates a force on the body to the resulting acceleration.

The ratio of the masses of two bodies is equal to the inverse of the ratio of their accelerations when the same force is applied to both.

$$\frac{m_X}{m_0} = \frac{a_0}{a_X}.$$

Here m_i and a_i are the mass and the acceleration of particle i respectively

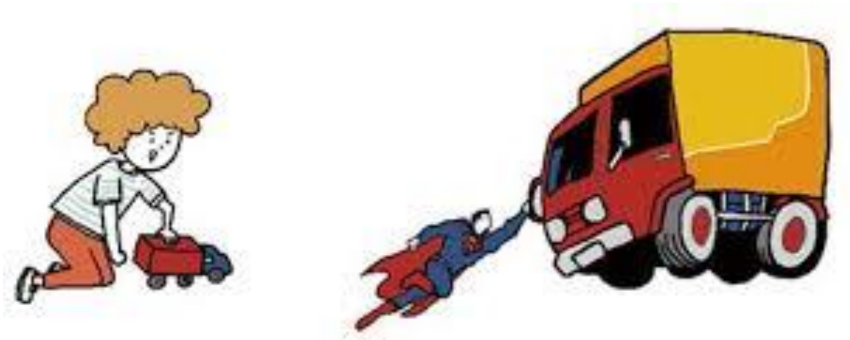
The tendency of an object to resist any attempt to change its velocity is called *inertia--慣性: 物體之速度被改變之難易度!*

物體之速度被改變之難易度一般以**Mass (質量)**之大小呈現之。

5.6: Newton's second law 牛頓第二定律:

The net force on a body is equal to the product of the body's mass and its acceleration.

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



In component form,

$$F_{\text{net},x} = ma_x, \quad F_{\text{net},y} = ma_y, \quad \text{and} \quad F_{\text{net},z} = ma_z.$$

The acceleration component along a given axis is caused *only by the sum of the force* components along that *same axis*, *and not by force components along any other axis.*

Units of force:

The SI unit of force is newton (N):

$$\boxed{1\ \text{N} = (1\ \text{kg})(1\ \text{m/s}^2) = 1\ \text{kgm/s}^2.}$$

TABLE 5-1

Units in Newton's Second Law (Eqs. 5-1 and 5-2)

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

Weight : $W = mg$ (mass – weight relationship)

5.6: Newton's second law; drawing a free-body diagram

✓In a free-body diagram, the only body shown is the one for which we are summing forces.

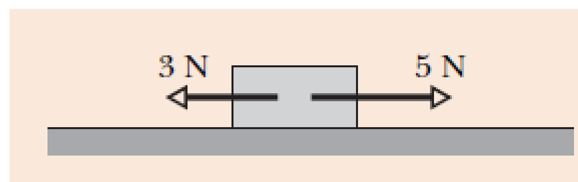
✓Each force on the body is drawn as a vector arrow with its tail on the body.

✓A coordinate system is usually included, and the acceleration of the body is sometimes shown with a vector arrow (labeled as an acceleration).

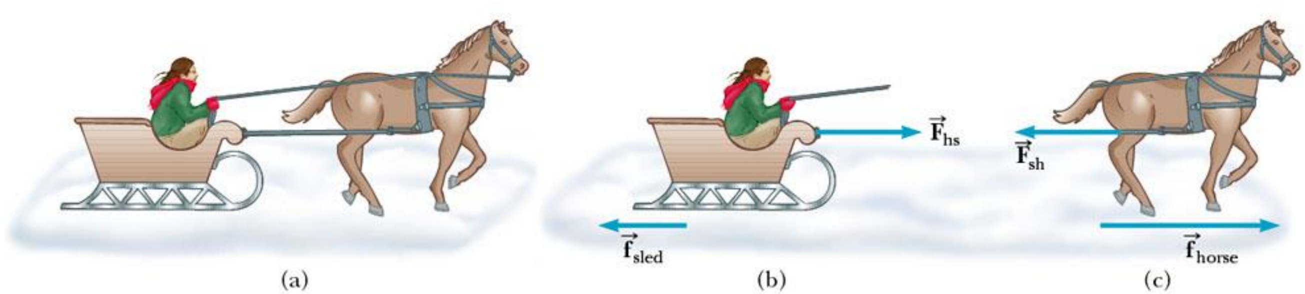
Free Body Diagram分離、獨立之物體圖:

~解決力學問題最有利之輔助圖!

要熟悉運用之!



The figure here shows two horizontal forces acting on a block on a frictionless floor.

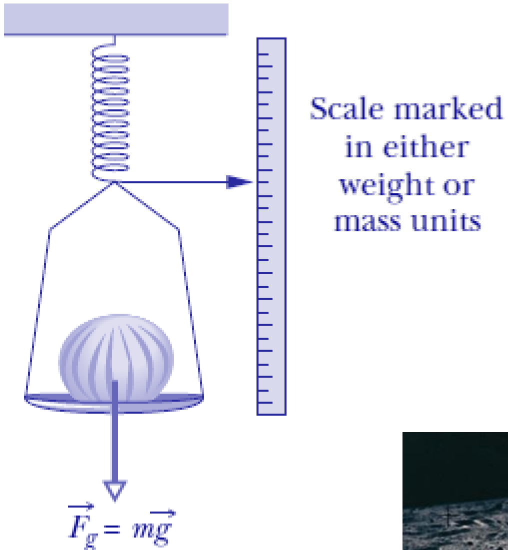


Gravitational Force 重力：

A gravitational force on a body is a certain type of pull that is directed toward a second body.

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

$$W = mg \text{ (weight)},$$



Suppose a body of mass *m* is in free fall with the free-fall acceleration of magnitude g. The force that the body feels as a result is:

$$F_g = m(g)$$

or $F_g = mg$.

5.7: Some particular forces

Normal Force:

When a body presses against a surface, the surface (even a seemingly rigid one) deforms and pushes on the body with a normal force, $\boldsymbol{F}_N$, that is perpendicular to the surface.

In the figure, forces F_g and F_N and are the only two forces on the block and they are both vertical. Thus, for the block we can write Newton's second law for a positive-upward *y axis*,

($F_{net,\,y}= ma_y$), as:

$$F_N - F_g = ma_y.$$

$$F_N - mg = ma_y.$$

$$F_N = mg + ma_y = m(g + a_y)$$

for any vertical acceleration a_y *of the table and block*

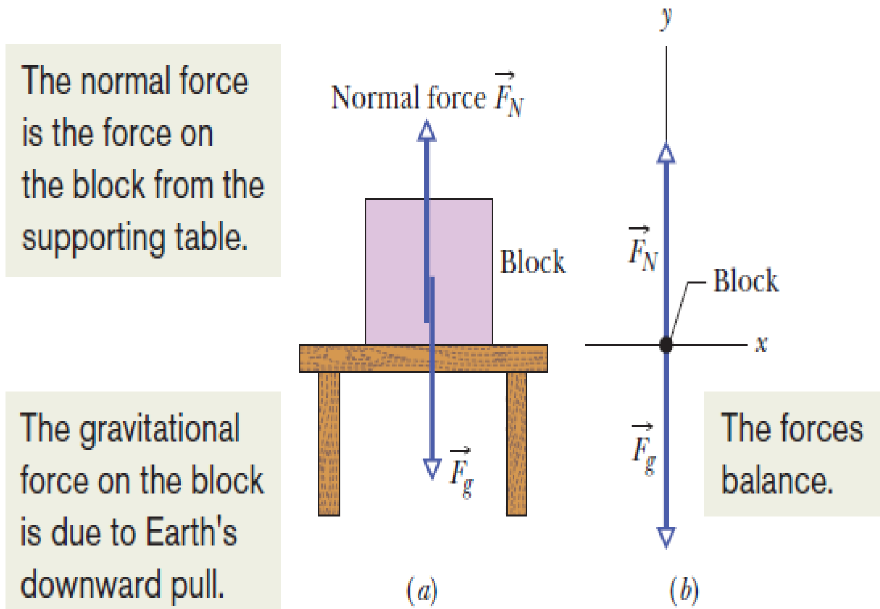
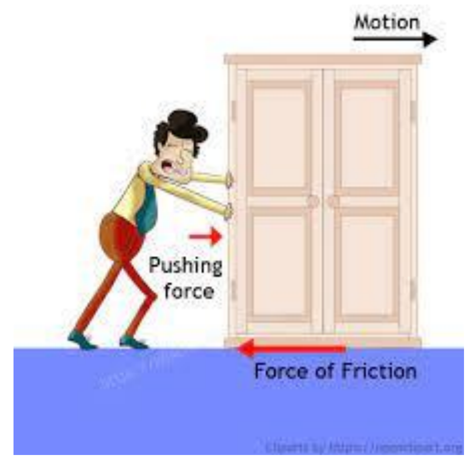


Fig. 5-7 (a) A block resting on a table experiences a normal force perpendicular to the tabletop. (b) The free-body diagram for the block.

5.7: Some particular forces

Friction

If we either slide or attempt to slide a body over a surface, the motion is resisted by a bonding between the body and the surface.



The resistance is considered to be single force called the frictional force, ***f***. This force is directed along the surface, opposite the direction of the intended motio

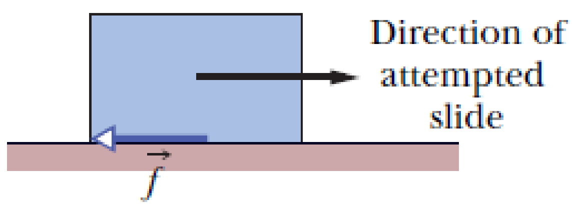


Fig. 5-8 A frictional force $\vec{f}$ opposes the attempted slide of a body over a surface.

5.7: Some particular forces

Tension

When a cord is attached to a body and pulled taut, the cord pulls on the body with a force *T directed away from the* body and along the cord.

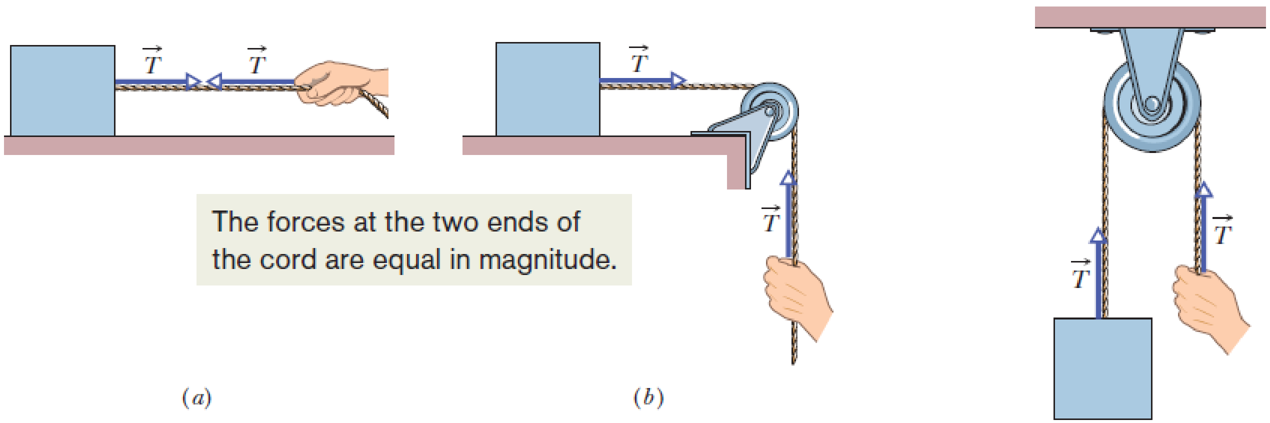


Fig. 5-9 (*a) The cord, pulled taut, is* under tension. If its mass is negligible, the cord pulls on the body and the hand with force ***T***, even if the cord runs around a massless, frictionless pulley as in *(b) and (c)*.

The following assumptions are made:

a. The rope has negligible mass compared to the mass of the object it pulls.

b. The rope does not stretch . If a pulley is used as in fig.(b) and fig.(c), we assume that the pulley is massless and frictionless.

5.8: Newton's Third Law (牛頓第三定律)

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

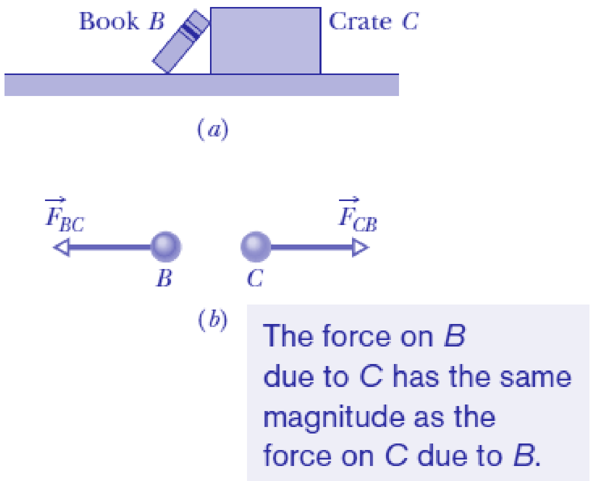


Fig. 5-10 (a) Book B leans against crate C. (b) Forces $\vec{F}_{BC}$ (the force on the book from the crate) and $\vec{F}_{CB}$ (the force on the crate from the book) have the same magnitude and are opposite in direction.

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

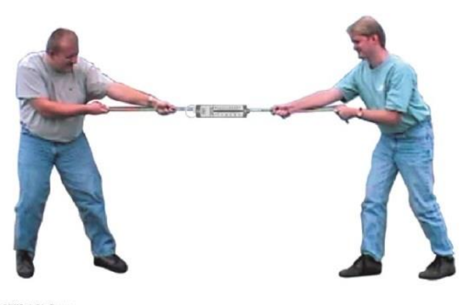
$$F_{BC} = F_{CB} \qquad \text{(equal magnitudes)}$$

or as the vector relation

$$\vec{F}_{BC} = -\vec{F}_{CB} \qquad \text{(equal magnitudes and opposite directions),}$$

- The minus sign means that these two forces are in opposite directions
- The forces between two interacting bodies are called a **third-law force pair.**

- 作用力=反作用力，大小相等、方向相反。但不能相抵消！
- 作用在不同物體上！



5.9: Applying Newton's Laws

Sample problem

Figure 5-12 shows a block S *(the sliding block) with mass M =3.3 kg. The block is free to move along a horizontal* frictionless surface and connected, by a cord that wraps over a frictionless pulley, to a second block H *(the hanging block), with mass m 2.1 kg. The cord and pulley have negligible* masses compared to the blocks (they are "massless"). The hanging block H *falls as the sliding block S accelerates* to the right. Find (a) the acceleration of block S, *(b) the acceleration* of block H, *and (c) the tension in the cord.*

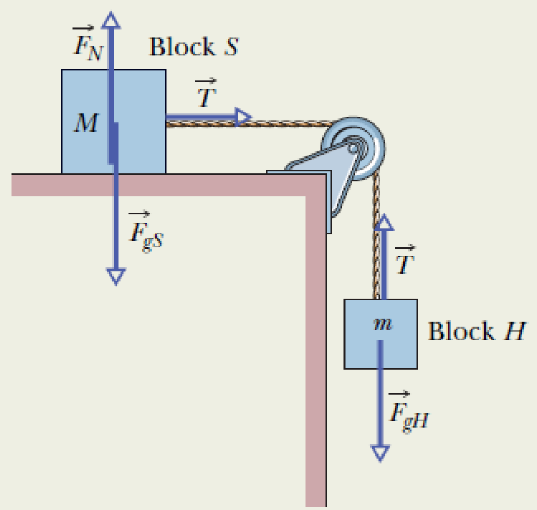


Fig. 5-13 The forces acting on the two blocks of Fig. 5-12.

Key Ideas:

1. Forces, masses, and accelerations are involved, and they should suggest Newton's second law of motion: $\vec{F} = m\vec{a}$
2. The expression $\vec{F} = m\vec{a}$ is a vector equation, so we can write it as three component equations.
3. Identify the forces acting on each of the bodies and draw free body diagrams.

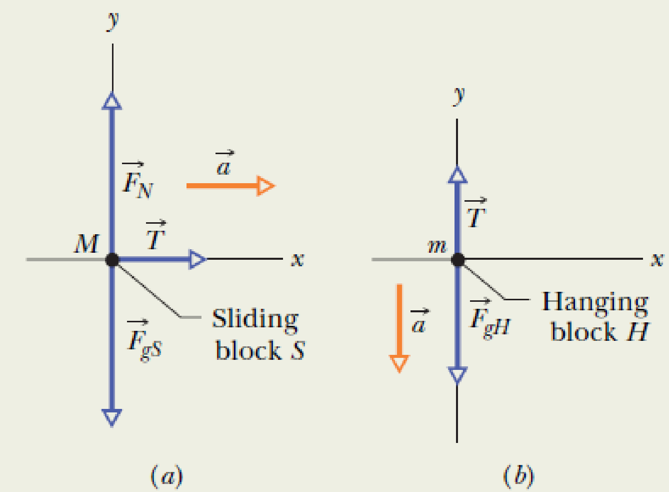


Fig. 5-14 (*a*) A free-body diagram for block S of Fig. 5-12. (*b*) A free-body diagram for block H of Fig. 5-12.

Sample problem, cont.

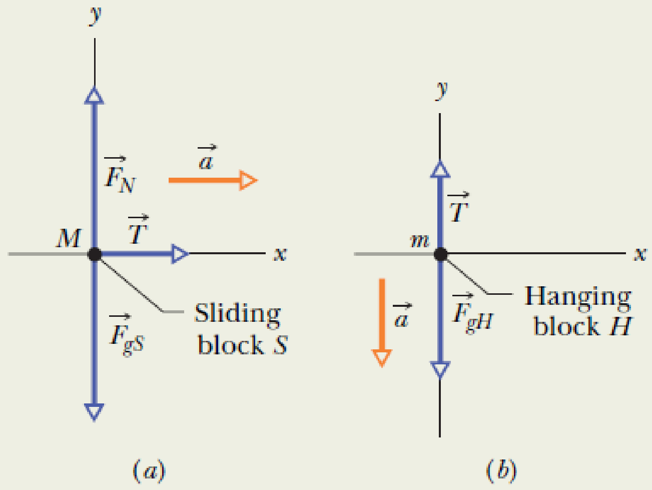


Fig. 5-14 (*a*) A free-body diagram for block *S* of Fig. 5-12. (*b*) A free-body diagram for block *H* of Fig. 5-12.

From the free body diagrams, write Newton's Second Law $\vec{F} = m\vec{a}$ in the vector form, assuming a direction of acceleration for the whole system.

Identify the net forces for the sliding and the hanging blocks:

$$F_{net,x} = Ma_x \quad F_{net,y} = Ma_y \quad F_{net,z} = Ma_z$$

For the sliding block, *S*, which does not accelerate vertically.

$$F_{net,y} = Ma_y \rightarrow F_N - F_{gS} = 0 \quad \text{or} \quad F_N = F_{gS}.$$

Also, for S, in the x direction, there is only one force component, which is T.

$$F_{net,x} = Ma_x \rightarrow T = Ma.$$

For the hanging block, because the acceleration is along the y axis,

$$T - F_{gH} = ma_y.$$

We eliminate the pulley from consideration by assuming its mass to be negligible compared with the masses of the two blocks.

With some algebra, $T - mg = -ma.$

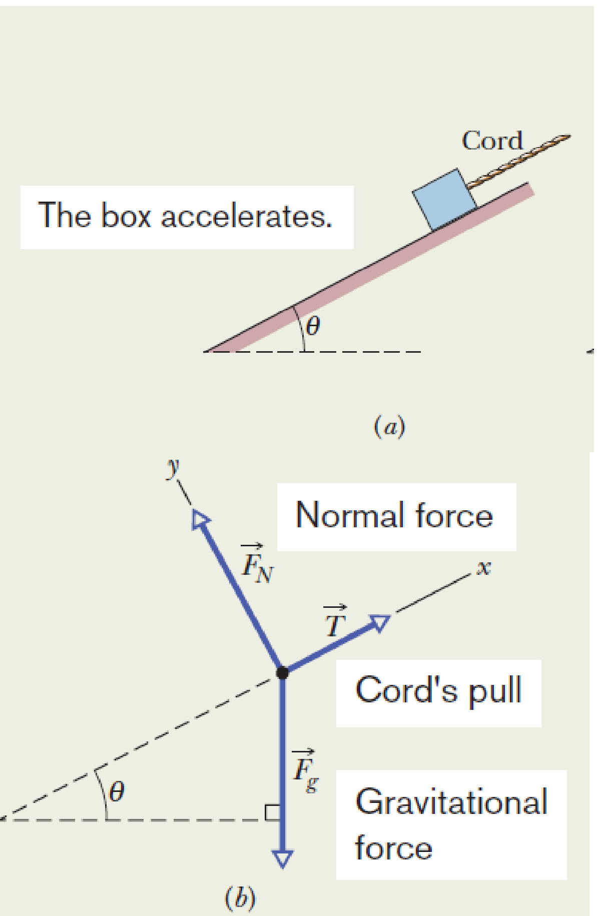
$$a = \frac{m}{M+m}g. = \frac{2.1\text{ kg}}{3.3\text{ kg} + 2.1\text{ kg}}(9.8\text{ m/s}^2) = 3.8\text{ m/s}^2$$

$$T = \frac{Mm}{M+m}g. = \frac{(3.3\text{ kg})(2.1\text{ kg})}{3.3\text{ kg} + 2.1\text{ kg}}(9.8\text{ m/s}^2) = 13\text{ N.}$$

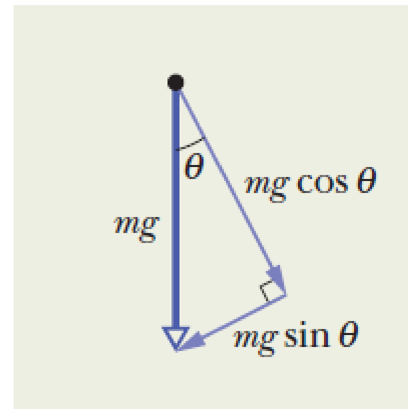
5.9: Applying Newton's Laws

Sample problem

In Fig. a, a cord pulls on a box of sea biscuits up along a frictionless plane inclined at θ= 30°.The box has mass m =5.00 kg, and the force from the cord has magnitude T =25.0 N. What is the box's acceleration component a along the inclined plane?



For convenience, we draw a coordinate system and a free-body diagram as shown in Fig. b. The positive direction of the x axis is up the plane. Force from the cord is up the plane and has magnitude T=25.0 N. The gravitational force is downward and has magnitude mg =(5.00 kg)(9.8 m/s2) =49.0 N. Also, the component along the plane is down the plane and has magnitude mg sin θ as indicated in the following figure. To indicate the direction, we can write the down-the-plane component as *-mg sin θ.*



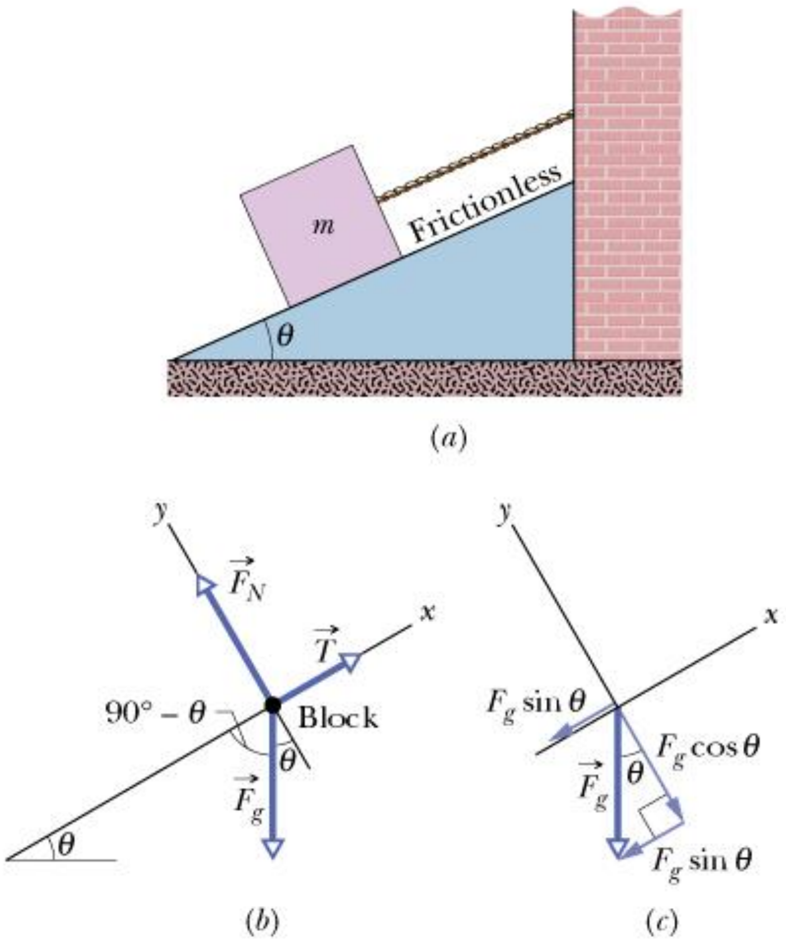
Using Newton's Second Law, we have :

$$T - mg \sin\theta = ma.$$

which gives: $$a = 0.100 \text{ m/s}^2,$$

The positive result indicates that the box accelerates up the plane.

Recipe for the application of Newton's law's of motion



1. Choose the system to be studied
2. Make a simple sketch of the system
3. Choose a convenient coordinate system
4. Identify all the forces that act on the system. Label them on the diagram
5. Apply Newton's laws of motion to the system

•••68 Figure 5-60 shows a section of a cable-car system. The maximum permissible mass of each car with occupants is 2800 kg. The cars, riding on a support cable, are pulled by a second cable attached to the support tower on each car. Assume that the cables are taut and inclined at angle $\theta = 35°$. What is the difference in tension between adjacent sections of pull cable if the cars are at the maximum permissible mass and are being accelerated up the incline at 0.81 m/s^2?

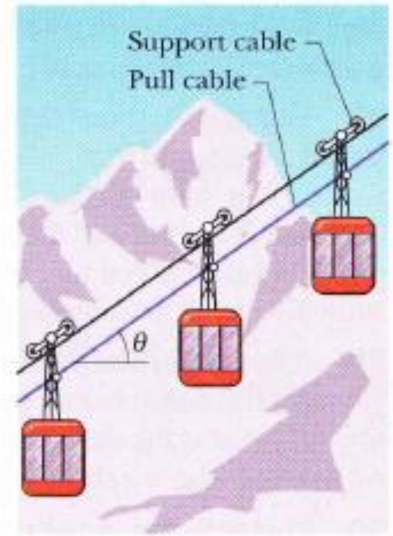
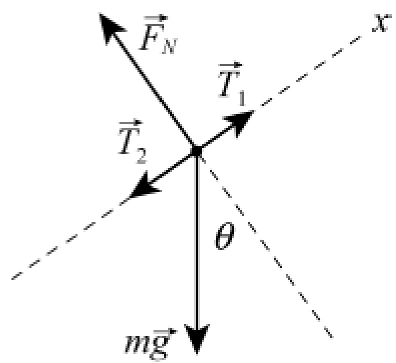


FIG. 5-60 Problem 68.

66. The free-body diagram is shown below.



Newton's second law for the mass m for the x direction leads to

$$T_1 - T_2 - mg\sin\theta = ma,$$

which gives the difference in the tension in the pull cable:

$$T_1 - T_2 = m(g\sin\theta + a) = (2750\text{ kg})\left[(9.8\text{ m/s}^2)\sin 35° + 0.81\text{ m/s}^2\right] = 1.8\times 10^4\text{ N}.$$

CH 5 習題:
10, 12, 13, 16, 36, and 51

電子感應護具操作:選手的腳穿上電子感應護具，擊中對手上半身的三個電子感應得分區，達到一定面積及力量，電子感應護具會把有關訊息透過肩上的裝置傳 到裁判積分計算器上，確認得到一分。由於頭部並沒有電子裝置，加上電子感應護具無法確認轉身腳法，所以這兩項攻擊得分與否仍然由裁判決定。