المزيد من الملفات بحسب الصف التاسع المتقدم والمادة فيزياء في الفصل الثاني	
5	كتاب الطالب

ch.4 Forces

Lesson 1 : what is the force

Force is an external effect on the system (object) and change object's motion ($a \neq 0$)or changes it's shape

Types of forces:

1- *contact force* in which one object has to be in contact (touch) with another object to exert a force on it
Examples :
pull force / push force / friction force (study later) / air resistance (kind of friction)
spring force has a special property of being linearly dependent on the change in length of the spring / normal force / drag force / tension force

2- *Field force* is the force exerted between the two objects without touching (contact)
Example : gravitational force / electric force / magnetic force /electromagnetic force/ week or strong nuclear force

Newton's first law and inertia

Newton's first law : if the object at rest it will remain at rest when the net force on the object equals zero , and if the object move with constant speed it will remain move with constant when the net force on the object equals zero

- Two situations for the net force on the object equals zero
  1- If the object at rest ($v = 0 \ \ so \ \ a = 0$)
  2- If the object move with constant speed ($v \ constant \ \ so \ \Delta v = 0 \ and \ \ a = 0$)
- The object at equilibrium state when $F_{net} = 0$, $a = 0$
- Two kinds of equilibrium
  1- static equilibrium when the object at rest (no motion)
  2- kinetic equilibrium when the object move with constant speed
- Inertia is the Tendency of an object to resist change in velocity (the object doesn't want to change its motion)
- Inertia will be exist on the object when the acceleration and the net force on the object equals zero $F_{net} = 0$, $a = 0$)
- if the object at rest it still want to be at rest because it still has inertia ($F_{net} = 0$, $a = 0$)
- If the object move with constant speed it still want to move with constant speed because it still has inertia ($F_{net} = 0$, $a = 0$)
- If you apply force on a rest object the object's velocity will change and the acceleration will be exist $a \neq 0$ so the net force will not equal zero $F_{net} \neq 0$ and inertia will disappear
- Inertia depends on the mass , the massive object has a big inertia and difficult to move (difficult to change its velocity)

ch.4 Forces

Q1) Which one move difficulty (chair or table)?

Table, because it has a big mass so big inertia and difficult to change its motion so difficult to move

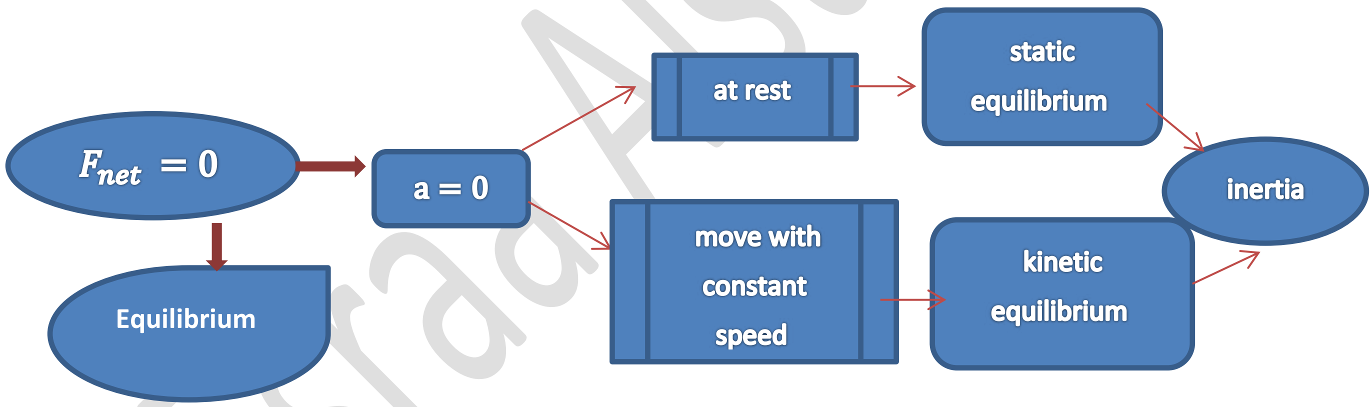
Q2) If your father drive the car with constant speed and you sit inside the car what will happen for you in each situation ?

a) **If your father press on the race (speeding up)**
   You will go backward because you still has inertia but the car's inertia gone
b) **If your father press on the brake (slowing down)**
   You will go forward because you still has inertia but the car's inertia gone
c) **If the car still move with constant speed**
   You will not move in the car because you and the car still have inertia

Q3) Why you must put the seatbelt on you in (the car or the games)

Because when your father press on the brake suddenly, you go forward because you still has inertia so the seatbelt will protect you (same explanation for the games)

Important summary:



Newton second law:

Q1) Which one will move fast (chair or table) when you exert same force on them?
Chair, because it has a less mass
$\uparrow a \;\; but \;\; \downarrow m \quad \rightarrow \quad inversly\ proprtional$

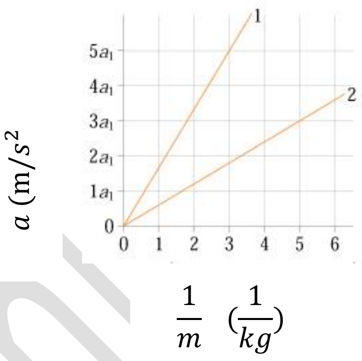
Q2) Which one will move fast when you exert (50 N OR 10N) on the chair?
50N , because it has big net force
$\uparrow a \;\; and \;\; \uparrow F_{net} \quad \rightarrow \quad linear\ proprtional$

ch.4 Forces

Newton second law : The acceleration of an object is linearly proportional to net force (mass constant) and inversely proportional to the mass (net force constant)

$$a = \frac{F_{net}}{m}$$

Q3) look to the graph and answer the following question



1) Which quantity in physics shows the slope ?

Slope = $\frac{a}{\frac{1}{m}} = a\,m = F_{net}\ equation$ **Slope =** F_{net}

2) Which one (1 or 2) has a big net force ?

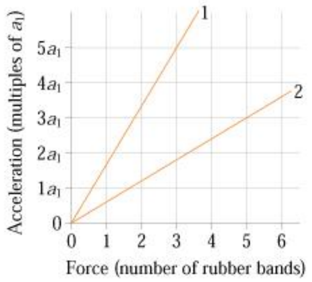
1 because it has the steeper line so it has the biggest slope and there is a linear proportional between slope with net force

$\theta_1 > \theta_2$

$slope_1 > slope_2$

$F_{net\,1} > F_{net\,2}$

Q4) look to the graph and answer the following question



1) Which quantity in physics shows the slope?

Slope = $\frac{a}{F_{net}} = \frac{1}{m}\ equation$

Slope = $\frac{1}{m}$

2) Which one (1 or 2) has a big mass ?

2 because it has the lowest slope but there is an inversely proportional between slope and mass

$\theta_1 > \theta_2$

$slope_1 > slope_2$

$m_1 < m_2$

Q5) What will happen for the <u>inertia</u> if the <u>mass increase twice</u>?

It will increase twice (linear proportional)

Q6) What will happen for <u>the acceleration</u> if the <u>mass increase twice</u>?

It will decrease to half (inversely proportional)

Q7) What will happen for the <u>acceleration</u> if the net force <u>(F net) increase twice</u> ?

It will increase twice (linear proportional)

ch.4 Forces

Newton third law

Newton's third law : each action has a reaction equals in magnitude and different in direction

$$\overrightarrow{F_{1,2}} = - \overrightarrow{F_{2,1}}$$

1) **Determine the action and the reaction in the picture?**

Action : the person exerted force in the boat and the boat go backward
Reaction the boat exerted force in the person and person go forward

2) **Why do you feel a pain when you push the table by your finger ?**

Because there is a reaction from the table to your figure

3) **Why always the forces is mutual?**-because always action has reaction

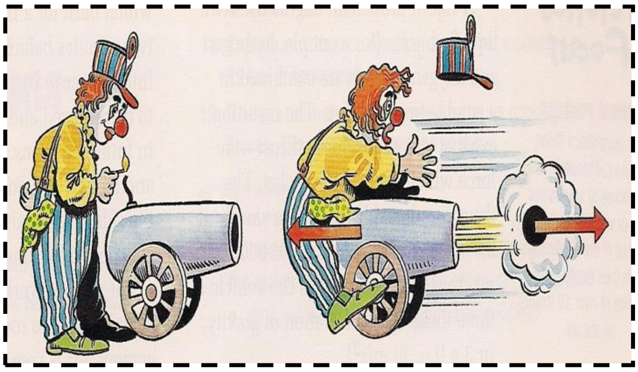
4) **How many objects affect in action and reaction?** Two objects

5) **Is the net force for action and reaction equal zero ?(important)**

Answer: No, it is impossible because we calculate the net force in one object(system) not in two objects so action will effect in one object and has a net force , and reaction will effect in another object and has another net force

6) **look to the picture below and answer the following question**

a) **Determine any action and reaction in the picture?**
action: force exerted from the cannon to the bomb and the bomb goes forward
reaction: force exerted from bomb to the cannon and cannon goes backward



b) **Why the cannon return back ?**
Because there is a reaction from the bomb

c) **Why the person return back ?**
Because there is a reaction from the cannon

d) Which one exerted a big force (cannon , bomb)?

Same force because action force equals reaction force

e) Which one has a big acceleration (cannon or bomb) ? why ?

bomb, because of the inversely proportional between mass and acceleration

Lesson 2: weight (Fg) and mass

Gravitational force is the force exerted from the planet to the object (system) or (by how much the planet tied the object) and always it's direction down ward

- always object weight = gravitational force (Fg)
- gravitational force equation $Fg = m \times g$
- there is a linear proportional between gravity force and object mass
- there is a linear proportional between gravity force and gravity acceleration
- the Cartesian coordinate for gravity force is (0$\hat{x}$-Fg $\hat{y}$)
- $N = \frac{Kg.m}{s^2}$

Q1) if the object mass = 4kg find the ratio between the object weight in the earth and the object weight in the moon (g_{moon} =1.62m/s^2/ g_{earth}= 9.81 m/s^2)

W_{eart}=$Fg(earth) = m \times g = 4 \times 9.81 = 39.24N$

W_{moon}=$Fg(moon) = m \times g = 4 \times 1.62 = 6.48N$

$$\frac{Fg(earth)}{Fg\,(moon)} = \frac{39.24}{6.48} = 6 \rightarrow Fg(earth) = 6\,Fg(moon)$$

Result: always your weight in the earth equals six times your weight in the moon

- **The difference between mass and weight show in table below**

	Weight (Fg)	Mass (m)
Definition	The force exerted from earth to the object	Amount of the matter in the object
Unite	N	Kg
Scale device	Spring balance	Simple balance
Direction	Downward	No direction
What will happen If the location change ?	Change/ because if the object very far from the center of the planet it's weight decreases because the gravity acceleration decreases	Not change

ch.4 Forces

- <u>The difference between gravity mass and inertia mass show in the table below</u>

Gravity mass	Inertia mass
it is responsible to gravitational interaction	It is responsible to the Tendency of an object to resist change in velocity
Mass of gravity and Mass of inertia is equal	

- **Example: if you are sit in the car and the car accelerating upward the hill**

  <u>Mass of gravity</u> responsible to be in the earth

  <u>Mass of inertia</u> responsible to return you back inside the car because you still have inertia

  And the two masses same because your mass not change

- **<u>A human's body weight</u> is in the range between 100 N an 1000N**

- **<u>Higgs particle</u> its responsible for imparting mass to all other particles with the mass of particular type of particle depending on how it interacts with the Higgs particle**

<u>Lesson 3 : tension force and Normal force (surface reaction)</u>

Tension force (T): is the force exerted from the rope or string to the object

Q) Find the tension force from the diagram if mass of the bucket=5kg

$F_g = mxg = 5x9.81 = 49N$

$F_{net} = F_T - F_g$

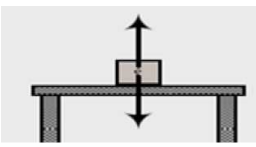
The object at rest so a= 0 and Fnet =0

$F_{net} = F_n - F_g \rightarrow o = F_T - F_g \rightarrow F_T = F_g = 49N$

Normal force (N): is the force exerted from surface to the object(system)

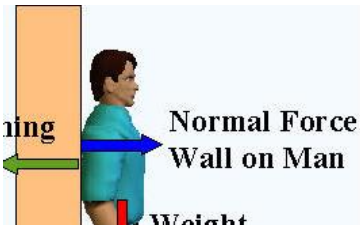
- **always it is a straight line make 90 degree with the surface and always goes outward the surface**

- **Examples:**
- **if there is a <u>horizontal surface</u> , the <u>normal force</u> will be <u>vertical</u>**

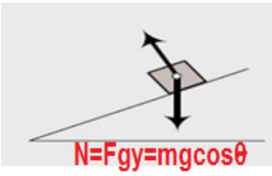


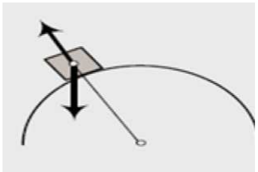
ch.4 Forces

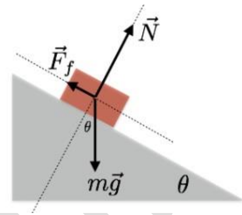
- if there is a <u>vertical surface</u> , the <u>normal force</u> will be <u>horizontal</u>



- if there is a <u>incline</u> <u>surface</u> , the <u>normal force</u> <u>will be incline</u> to make 90 with the surface



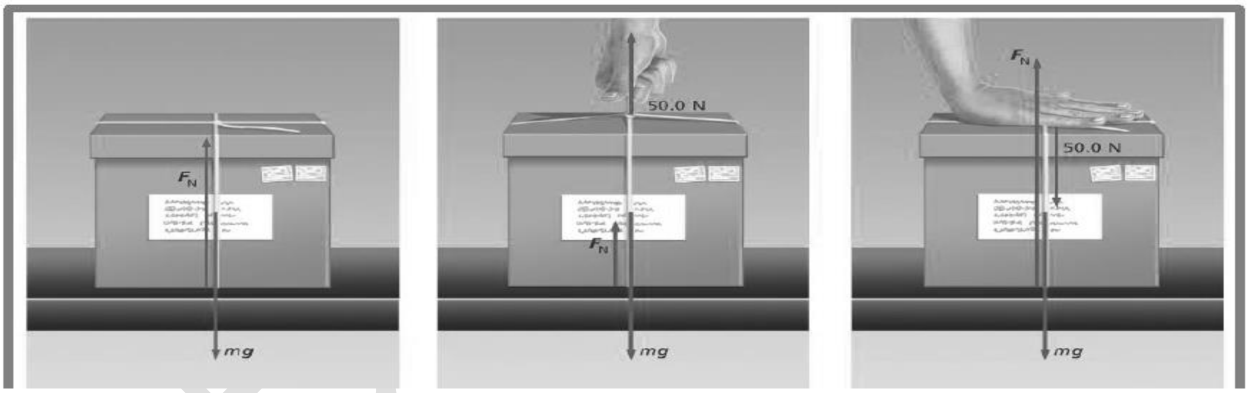




Q) Look to the figure below and find the normal force in each picture then compare it with gravity force (assume the mass of the system (box) = 7kg)

<u>Solve the problem</u>:

$$F_g = mxg = 7x9.81 = 69N$$



Picture 1	Picture 2	Picture 3
$F_{net} = F_n - F_g$	$F_{net} = F_n + 50 - F_g$	$F_{net} = F_n - 50 - F_g$
the object at rest so	the object stil at rest so	the object stii at rest so
a= 0 and Fnet =0	a= 0 and Fnet =0	a= 0 and Fnet =0
$F_{net} = F_n - F_g$	$0 = F_n + 50 - F_g$	$0 = F_n + 50 - F_g$
$o = F_n - F_g$	$F_n = F_g - 50 = 69 - 50 = 19N$	$F_n = F_g + 50 =$
$F_n = F_g = 69N$		$F_n = 69 + 50 = 109N$
$F_n = F_g$	$F_n < F_g$	$F_n > F_g$

ch.4 Forces

Lesson 3 :Friction force

It is an interaction between the object (system) atoms and surface atoms

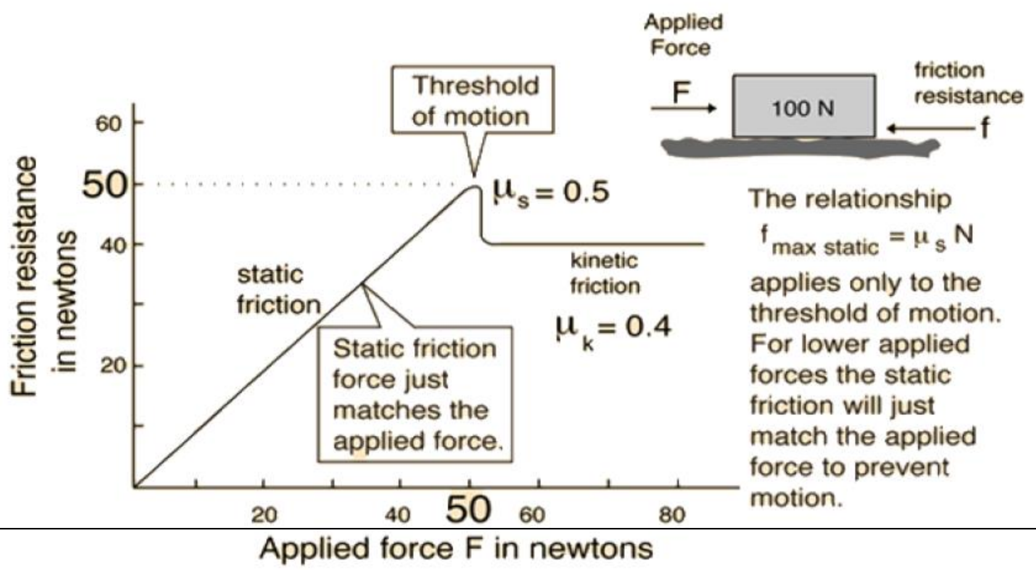
- **Friction always resists the motion so it is in opposite direction of the object motion**
- **Friction is independent of the speed of the object**
- **Friction is independent of the size of the contact area between object and surface**
- **Friction is depend on the roughness of the surface**
- **No friction for smooth surface**
- **There is a linear proportional between normal force (N) and friction force f**
- **There is two kinds of friction**
  1- **Static friction: it is an opposing force that keeps the object from moving (no move) . it is increase as the applied force increases until the maximum static friction force increase possible between the two surfaces**
  2- **Kinetic friction: it is an opposing force on an object when it is moving. It stays constant when the object is in motion.**
- **The coefficient of friction(μ)depends on the composition and qualities of the surfaces in contact , and always it is a decimal number $0 < \mu < 1$**

As shown as in the graph

- **If you apply a 20 N on the object, the object will not move (Fnet = 0) because there is another force(static friction) in the other direction equals the applied force magnitude** $Fnet = F_a - f_s = 20 - 20 = 0$
- **If you increase the applied force, the static friction will increase and the net force still equals zero ,until the applied force equals 50N the object will be in threshold of motion ,in this point the object still at rest and net force equals zero but the static friction at maximum value** $Fnet = F_a - f_{s,max} = 50 - 50 = 0$
- **If you increase the applied force more than 50N , $F_a = 60N$ the object will move and the friction will decrease less than 50N and equals 40N then the friction will not change if you increase the applied force so the kind of friction here is a Kinetic friction (because the object is move with a constant resistance force)**

$$Fnet = F_a - f_k = 60 - 40 = 20N$$

- **Always the coefficient of static friction ($\mu_{s,max}$)bigger than the coefficient of kinetic friction (μ_k)** $\mu_{s,max} > \mu_k$ **because** $f_{s,max} > f_k$



kinetic friction equation	static friction equation	
$f_k = \mu_k F_n$	$f_{s,max} = \mu_s F_n$	

$f_k\ [N] = kinetic\ friction$

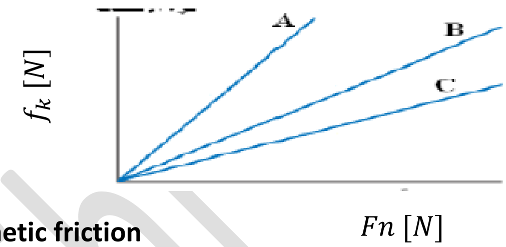
$f_{s,max}\ [N] = maximum\ static\ friction$

$F_n\ [N] = normal\ force$

$\mu_k\ [-] = coffiecent\ kinetic\ friction$

$\mu_s\ [-] = coffiecent\ static\ friction$

Q1)Look to the graph and answer the following question



1- **Which quantity in physics represents the slop?**

explain: slope in math = $\frac{\Delta y}{\Delta x}$

Convert math to physics

x-axis represents normal force but y- axis represent kinetic friction

so

slop in physics = $\frac{f_k}{F_N}$ → = μ_k coefficient kinetic friction equation

answer : the slope = μ_k

2- **Which one (A,B,C) has the biggest (μ_k)coefficient kinetic friction ?**

(A) because it has the steeper line and has the biggest slope so biggest μ_k

Q2) If you applied force on an object has mass 25kg look to graph 2 and answer the following question

1- **Find the coefficient friction when the object in threshold of motion**

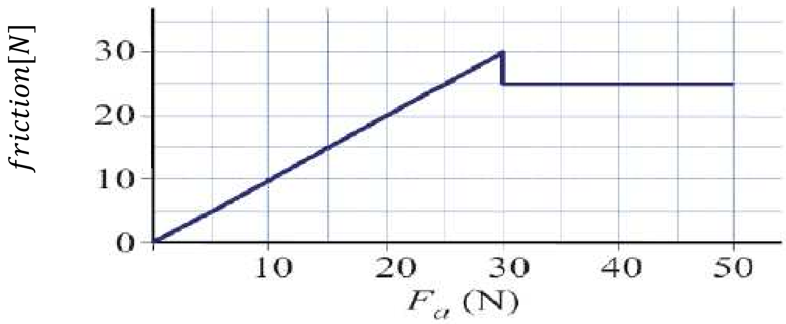
$$\mu_s = \frac{f_{s,max}}{F_n} = \frac{f_{s,max}}{F_g} = \frac{f_{s,max}}{mg} = \frac{30}{25\times 9.81} = 0.12$$

2- **Find the coefficient friction when the object move**

$$\mu_s = \frac{f_k}{F_n} = \frac{f_k}{F_g} = \frac{f_k}{mg} = \frac{25}{25\times 9.81} = 0.1$$

3- **What is the acceleration when he person applied 40N?**

$$a = \frac{F_{net}}{m} = \frac{F_a - f_k}{m} = \frac{40-25}{25} = 0.6$$

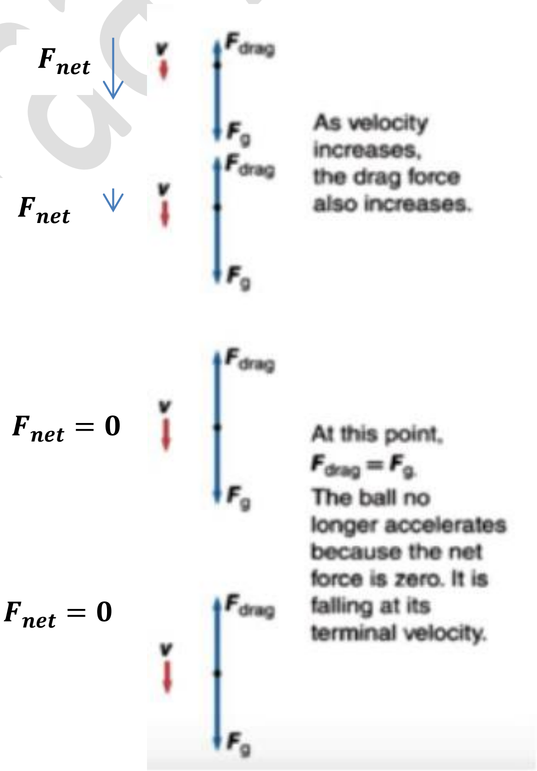


ch.4 Forces

Drag force

- Drag force is the force exerted from the fluid (liquid or gas) to the object moving in the fluid and always the drag force is opposite direction to the object motion
- Tribology is the science of friction
- in general , the magnitude of friction force in liquid or gases will be expressed as $F_{friction} = K_0 + K_1 v + K_2 v^2 + \cdots$
- When velocity for the object increases the drag force as air resistance will increase , we can neglect the linear term from the friction equation when the velocity is high so the drag force equation $F_{friction} = F_{drag} = Kv^2$
- For low velocity friction equation will be $F_{friction} = K v$ this form applies biological process as bacteria move through liquid , and we will use it when analyzing the sinking of an object in a fluid as a small stone or fossil shell in water
- Air resistance is an example of drag force because always air resistance opposes to the object motion

Free body diagram for the person falling



ch.4 Forces

Important note for the diagram:

- The drag force in this example is the air resistance
- When the person goes down his weight (Fg)does not change
- When the person goes down the velocity increases so the drag force increases, too
- When the person goes down Fnet decreases because drag force increases Fnet = F_d- Fg
- In one point in the air(fluid) ,drag force equals person weight(Fg) and Fnet = 0 $F_d = F_g$,the person will complete his motion with the final velocity which reach it in this point(terminal velocity)
- *Terminal velocity* is a constant velocity when $F_d = F_g$ and Fnet = 0
- *the terminal speed* equation $F_{drag} = F_g = Kv^2$

$$\rightarrow v_{terminal} = \sqrt{\frac{mg}{K}}$$

In the beginning, the drag force was low because the velocity was low when velocity increases, if the person continues falling ,the drag force increases more; and it stops increasing when drag force equals the weight of the person ,at this point the person completes his motion with constant speed (terminal) velocity

* **The factors effect on terminal speed** • $v_{terminal} = \sqrt{\frac{mg}{K}}$

1- Object mass when K is constant , the massive one will be fast

2-Drag coefficient , there is inversely proportional between(K)and $v_{terminal}$

* **The factors effect on the constant of drag force** $K = \frac{1}{2} C_P A \rho$

1- Size of cross sectional area (A) exposed to the air stream (linearly proportional between(K) and (A)
2- Air density ρ (linearly proportional)
3- Drag constant C_P *shows* (the shape of the object , on its inclination relative to the direction of motion on air viscosity and compressibility)

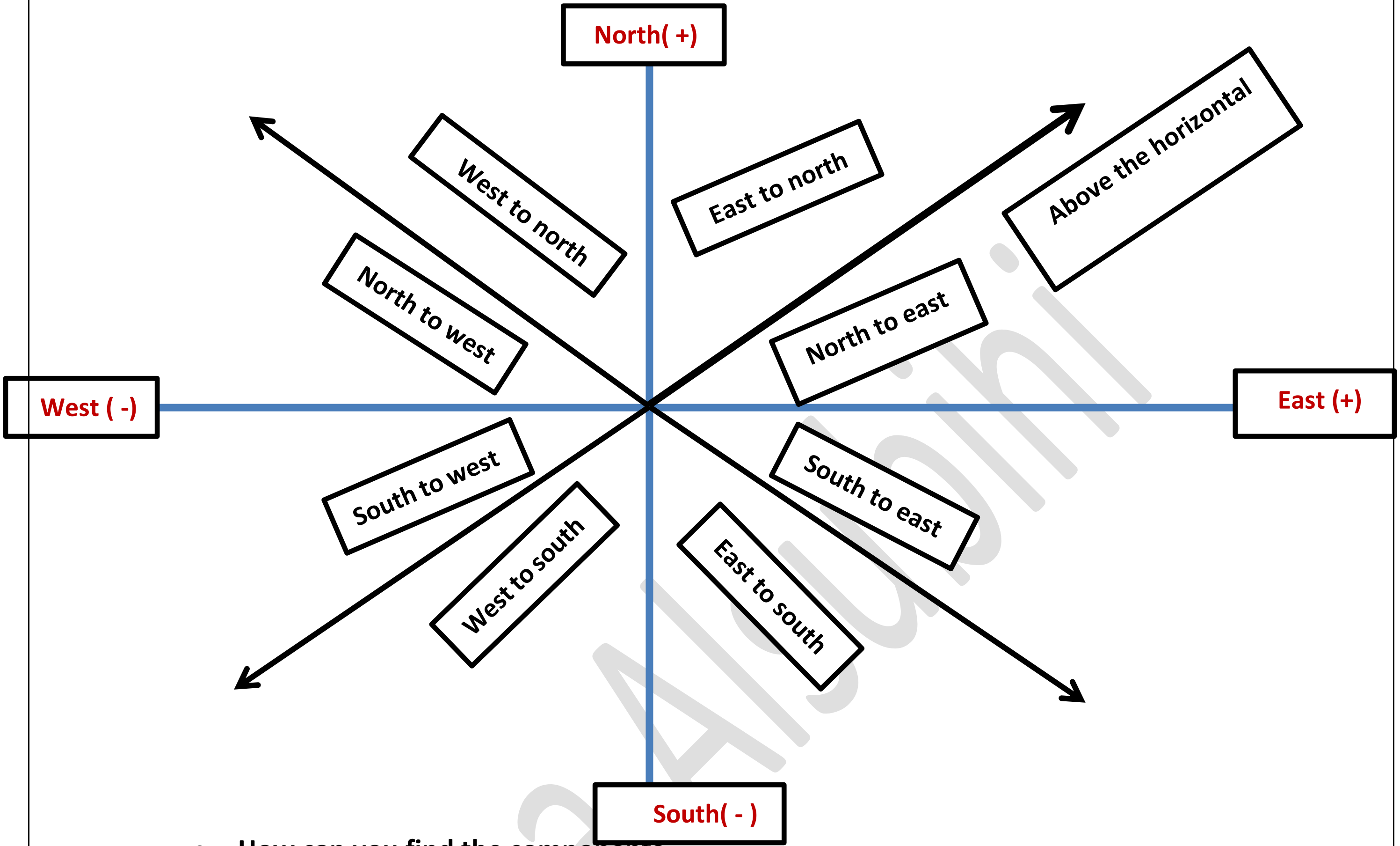
Q1) Why do you open the parachute when you are falling?

Answer: because the surface area of the parachute is big so constant drag (K) will be increase but velocity will be decrease because of the inversely proportional between (K and $v_{terminal}$) so when the terminal speed decreases it protects the person when reaching the ground

ch.4 Forces

Vectors

- Any vector with angle has a value in x- axis called horizontal component and has a value in y- axis called vertical component

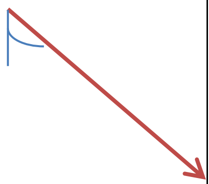


- How can you find the components

Q1) Find the force's components if F=20N with an angle 30 ° east to south ?

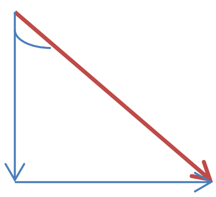
Steps:

1- draw the vector between east and south



2- the angle must be near the second ward (south) from east to south

3- try to draw right triangle and make sure the angle must be between two tails



4- the adjacent component to the angle will be F multiply cos angle , but the opposite component to the angle will be F multiply sin angle

So in this question , because the vertical component adjacent to the angle the equation will be

$$F_y = F\cos\theta = 20\cos 30 = 17.3N$$

but the horizontal component opposite to the angle ,the equation will be

$$F_x = F\sin\theta = 20\sin 30 = 10N$$

Q2) Find the net force if one force equals 30N right and the other force equals 40N left

We will add the forces with the directions (only you can use this equation if all the forces in one axis (in this question the forces in x- axis))

$$\overrightarrow{F_{net}} = \overrightarrow{F_1} + \overrightarrow{F_2} = 30 + -40 = -10\ N$$

The force's magnitude equals 10 N and it's direction to the left

- How can you find the net vector if one vector in x- axis and the other in y-axis

Q 3) If the horizontal force F_x= 3N and vertical force $F_y = -5N$ find the magnitude and direction of the net force

1- To find the magnitude we will use fethagorth rule because one vector in x-axis and the other vector in y- axis $\quad F_{net} = \sqrt{F_x{}^2 + F_y{}^2}$

$$F_{net} = \sqrt{3^2 + 5^2} = 5.8N$$

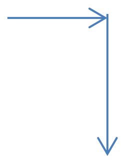
2- To find the direction you must draw the net force (follow the steps)

Steps:

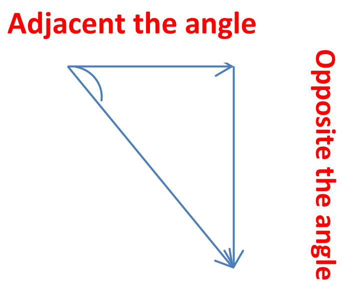
a. draw the horizontal vector east because F_x + (x + east or right / x- west or left

b. draw the vertical vector south because F_y − (y+ north or up / y- south or down

c. you must put the tail of vertical vector on the head of horizontal vector



d. draw the net force from the tail of one component to the head of the other component



ch.4 Forces

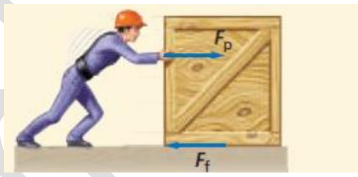
e. make sure that the length of vector y must be bigger than the length of vector x because in this question the magnitude of vector y bigger than the magnitude of vector x

f. use $\theta = \tan^{-1}\frac{opposite\ the\ angle}{adjacent\ the\ angle}$

$\theta = \tan^{-1}\frac{5}{3} = 59\,^{\circ}$ south to east Or the angle θ = 59 – 90 = 31° east to south

Problem solving

1- You push a 25 kg wooden box a cross a wooden floor at a constant speed of 1m/s how much force do you exert on the box if the coefficient of kinetic friction is 0.33?

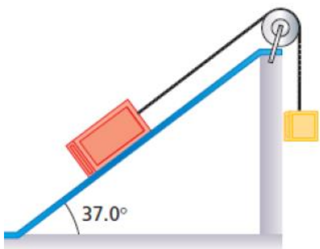


2- One student applied a force 40N on a rough surface with 45° above the horizontal (north to east) ,what is the acceleration if the coefficient of kinetic friction is 0.13?

3- Two blocks are connected by string over a frictionless a massless pulley such that one is resting on an inclined plane and the other is hanging over the top edge of the plane . as shown in the diagram below . the hanging block has a mass of 16kg and the one on the plane has a mass of 8 kg . the coefficient of kinetic friction between the block and the inclined plane is 0.23 the blocks are released from rest

a- what is the acceleration of the block ?

b- What is the tension in the string connecting the block ?



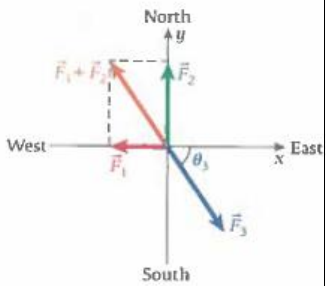
ch.4 Forces

EXAMPLE 4.1 **Modified Tug-of-War**

In a tug-of-war competition, two teams try to pull each other across a line. If neither team is moving, then the two teams exert equal and opposite forces on a rope. This is an immediate consequence of Newton's Third Law. That is, if one team pulls on the rope with a force of magnitude F, the other team necessarily has to pull on the rope with a force of the same magnitude but in the opposite direction.

PROBLEM

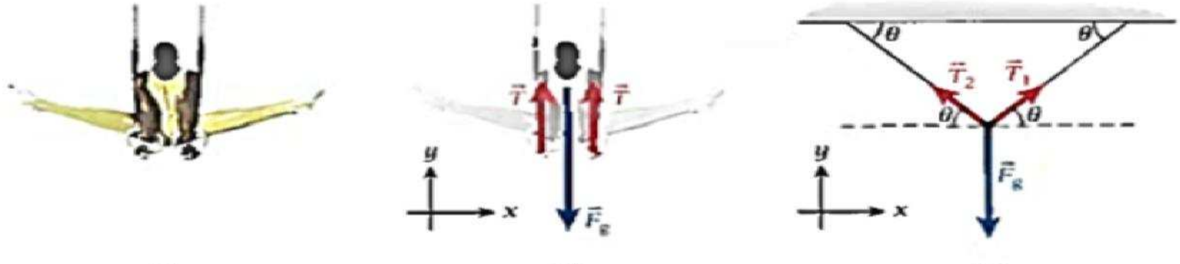
Now let's consider the situation where three ropes are tied together at one point, with a team pulling on each rope. Suppose team 1 is pulling due west with a force of 2750 N, and team 2 is pulling due north with a force of 3630 N. Can a third team pull in such a way that the three-team tug-of-war ends at a standstill, that is, no team is able to move the rope? If yes, what is the magnitude and direction of the force needed to accomplish this?



EXAMPLE 4.2 Still Rings

A gymnast of mass 55 kg hangs vertically from a pair of parallel rings (Figure 4.10a).

PROBLEM 1
If the ropes supporting the rings are vertical and attached to the ceiling directly above, what is the tension in each rope?



(a) (b) (c)

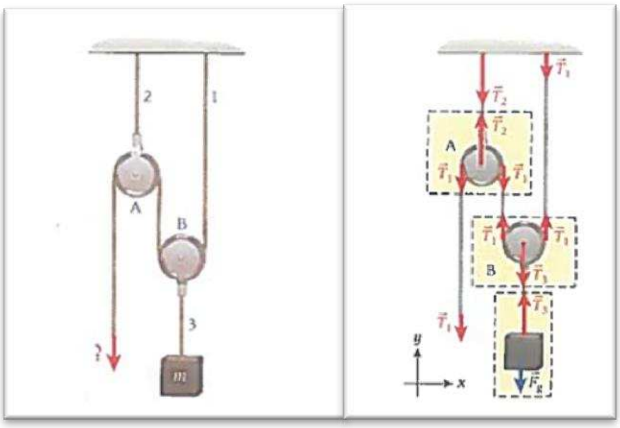
PROBLEM 2
If the ropes are attached so that they make an angle $\theta = 45°$ with the ceiling (Figure 4.10c), what is the tension in each rope?

PROBLEM 3
How does the tension in the ropes change as the angle θ between the ceiling and the ropes becomes smaller and smaller?

ch.4 Forces

From the adjacent figure prove that

$$T_1 = \frac{1}{2}\,mg$$

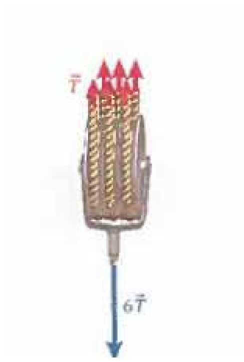


This result means that the force we need to apply to suspend the object of mass m in this way is only half as large as the force we would have to use to simply hold it up with a rope, without pulleys. This change in force is why a pulley is called a *force multiplier*.

Even greater force multiplication is achieved if rope 1 passes a total of n times over the same two pulleys. In this case, the force needed to suspend the object of mass m is

$$T = \frac{1}{2n}mg. \qquad (4.9)$$

Figure 4.13 shows the situation for the lower pulley in Figure 4.12 with $n = 3$. This arrangement results in $2n = 6$ force arrows of magnitude T pointing up, able to balance a downward force of magnitude $6T$, as expressed by equation 4.9.



رحمك الله يا والدي

ch.4 Forces

EXAMPLE 4.3 Two Books on a Table

We have considered the simple situation of one object (a laptop computer) supported from below and held at rest. Now let's look at two objects at rest: two books on a table (Figure 4.14a).

PROBLEM

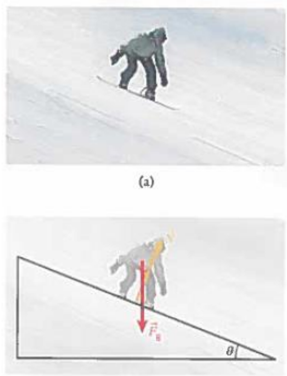
What is the magnitude of the force that the table exerts on the lower book?

(a)

SOLVED PROBLEM 4.1 Snowboarding

PROBLEM

A snowboarder (mass 72.9 kg, height 1.79 m) glides down a slope with an angle of 22° with respect to the horizontal (Figure 4.15a). If we can neglect friction, what is his acceleration?



(a)

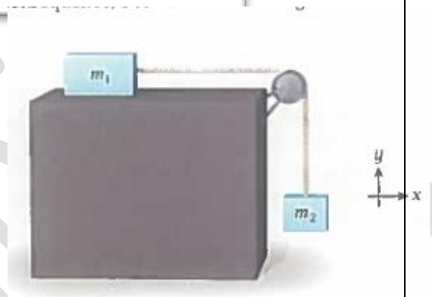
(b)

SOLVED PROBLEM 4.2 Two Blocks Connected by a Rope

In this classic problem, a hanging mass causes the acceleration of a second mass that is resting on a horizontal surface (Figure 4.16a). Block 1, of mass $m_1 = 3.00$ kg, rests on a horizontal frictionless surface and is connected via a massless rope (for simplicity, oriented in the horizontal direction) running over a massless pulley to block 2, of mass $m_2 = 1.30$ kg.

PROBLEM

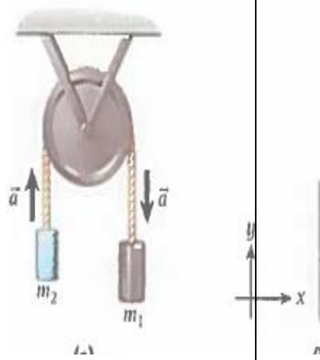
What is the acceleration of block 1 and of block 2?



(a)

EXAMPLE 4.4 Atwood Machine

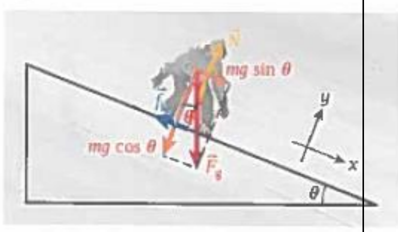
The Atwood machine consists of two hanging weights (with masses m_1 and m_2) connected via a rope running over a pulley. For now, we consider a friction-free case, where the pulley does not move, and the rope glides over it. (In Chapter 10 on rotation, we will return to this problem and solve it with friction present, which causes the pulley to rotate.) We also assume that $m_1 > m_2$. In this case, the acceleration is as shown in Figure 4.17a. (The formula derived in the following is correct for any case. If $m_1 < m_2$, then the value of the acceleration, a, will have a negative sign, which will mean that the acceleration direction is opposite to what we have assumed in working the problem.)



ch.4 Forces

EXAMPLE 4.6 Realistic Snowboarding

Let's reconsider the snowboarding situation from Solved Problem 4.1, but now include friction. A snowboarder moves down a slope for which $\theta = 22°$. Suppose the coefficient of kinetic friction between his board and the snow is 0.21, and his velocity, which is along the direction of the slope, is measured as 8.3 m/s at a given instant.



PROBLEM 1
Assuming a constant slope, what will be the speed of the snowboarder along the direction of the slope when he is 100 m farther down the slope?

EXAMPLE 4.5 Collision of Two Vehicles

Suppose that an SUV of mass $m = 3260$ kg has a head-on collision with a subcompact car of mass $m = 1194$ kg and exerts a force of magnitude 2.9×10^5 N on the subcompact.

PROBLEM
What is the magnitude of the force that the subcompact exerts on the SUV in the collision?

ch.4 Forces

EXAMPLE 4.7 Sky Diving

An 80.0-kg skydiver falls through air with a density of 1.15 kg/m^3. Assume that his drag coefficient is $c_d = 0.570$. When he falls in the spread-eagle position, as shown in Figure 4.20a, his body presents an area $A_1 = 0.940$ m^2 to the wind, whereas when he dives head first, with arms close to the body and legs together, as shown in Figure 4.20b, his area is reduced to $A_2 = 0.210$ m^2.

PROBLEM

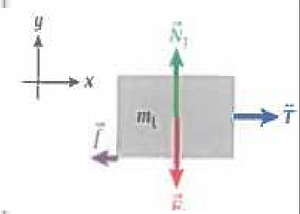
What are the terminal speeds in both cases?

(a)

(b)

EXAMPLE 4.8 Two Blocks Connected by a Rope—with Friction

We solved this problem in Solved Problem 4.2, with the assumptions that block 1 slides without friction across the horizontal support surface and that the rope slides without friction across the pulley. Here we will allow for friction between block 1 and the surface it slides across. For now, we will still assume that the rope slides without friction across the pulley. (Chapter 10 will present techniques that let us deal with the pulley being set into rotational motion by the rope moving across it.)



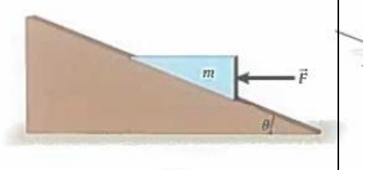
١

PROBLEM 1

Let the coefficient of static friction between block 1 (mass $m_1 = 2.3$ kg) and its support surface have a value of 0.73 and the coefficient of kinetic friction have a value of 0.60. (Refer back to Figure 4.16.) If block 2 has mass $m_2 = 1.9$ kg, will block 1 accelerate from rest?

SOLVED PROBLEM 4.3 Wedge

A wedge of mass $m = 37.7$ kg is held in place on a fixed plane that is inclined by an wangle $\theta = 20.5°$ with respect to the horizontal. A force $F = 309.3$ N in the horizontal direction pushes on the wedge, as shown in Figure 4.23a. The coefficient of kinetic friction between the wedge and the plane is $\mu_k = 0.171$. Assume that the coefficient of static friction is low enough that the net force will move the wedge.



(a)

SOLVED PROBLEM 4.4 Two Blocks

Two rectangular blocks are stacked on a table as shown in Figure 4.24a. The upper block has a mass of 3.40 kg, and the lower block has a mass of 38.6 kg. The coefficient of kinetic friction between the lower block and the table is 0.260. The coefficient of static friction between the blocks is 0.551. A string is attached to the lower block, and an external force $\vec{F}$ is applied horizontally, pulling on the string as shown.

PROBLEM

What is the maximum force that can be applied to the string without having the upper block slide off?

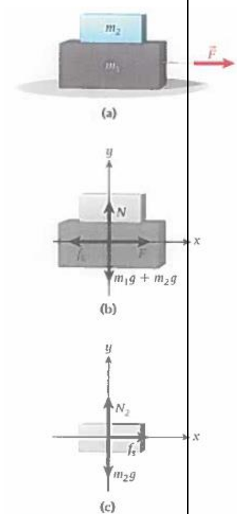


FIGURE 4.24 (a) Two stacked blocks

EXAMPLE 4.9 Pulling a Sled

Suppose you are pulling a sled across a level snow-covered surface by exerting constant force on a rope, at an angle θ relative to the ground.

PROBLEM 1

If the sled, including its load, has a mass of 15.3 kg, the coefficients of friction between the sled and the snow are $\mu_s = 0.076$ and $\mu_k = 0.070$, and you pull with a force of 25.3 N on the rope at an angle of 24.5° relative to the horizontal ground, what is the sled's acceleration?

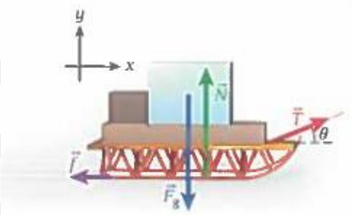


FIGURE 4.25 Free-body diagram of the sled and its load.

PROBLEM 2

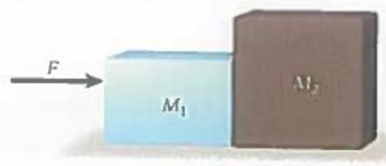
What angle of the rope with the horizontal will produce the maximum acceleration of the sled for the given value of the magnitude of the pulling force, T? What is that maximum value of a?

4.32 Two blocks are in contact on a frictionless, horizontal tabletop. An external force, $\vec{F}$, is applied to block 1, and the two blocks are moving with a constant acceleration of 2.45 m/s². Use $M_1 = 3.20$ kg and $M_2 = 5.70$ kg.

a) What is the magnitude, F, of the applied force?

b) What is the contact force between the blocks?

c) What is the net force acting on block 1?



4.43 Arriving on a newly discovered planet, the captain of a spaceship performed the following experiment to calculate the gravitational acceleration for the planet: She placed masses of 100.0 g and 200.0 g on an Atwood device made of massless string and a frictionless pulley and measured that it took 1.52 s for each mass to travel 1.00 m from rest.

a) What is the gravitational acceleration for the planet?

b) What is the tension in the string?

ch.4 Forces

•4.44 A store sign of mass 4.25 kg is hung by two wires that each make an angle of $\theta = 42.4°$ with the ceiling. What is the tension in each wire?

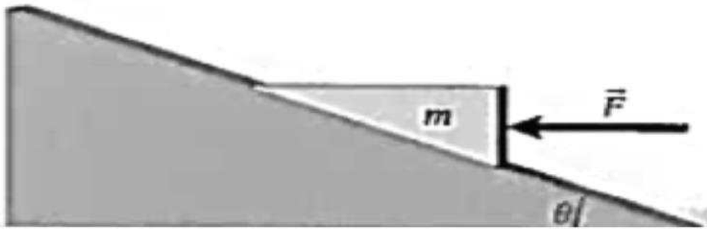
•4.45 A crate of oranges slides down an inclined plane without friction. If it is released from rest and reaches a speed of 5.832 m/s after sliding a distance of 2.29 m, what is the angle of inclination of the plane with respect to the horizontal?

ch.4 Forces

•4.46 A load of bricks of mass $M = 200.0$ kg is attached to a crane by a cable of negligible mass and length $L = 3.00$ m. Initially, when the cable hangs vertically downward, the bricks are a horizontal distance $D = 1.50$ m from the wall where the bricks are to be placed. What is the magnitude of the horizontal force that must be applied to the load of bricks (without moving the crane) so that the bricks will rest directly above the wall?

•4.63 A skier starts with a speed of 2.00 m/s and skis straight down a slope with an angle of 15.0° relative to the horizontal. The coefficient of kinetic friction between his skis and the snow is 0.100. What is his speed after 10.0 s?

••4.65 A wedge of mass $m = 36.1$ kg is located on a plane that is inclined by an angle $\theta = 21.3°$ with respect to the horizontal. A force $F = 302.3$ N in the horizontal direction pushes on the wedge, as shown in the figure. The coefficient of kinetic friction between the wedge and the plane is 0.159. What is the acceleration of the wedge along the plane?



ch.4 Forces

••4.64 A block of mass $m_1 = 21.9$ kg is at rest on a plane inclined at $\theta = 30.0°$ above the horizontal. The block is connected via a rope and massless pulley system to another block of mass $m_2 = 25.1$ kg, as shown in the figure. The coefficients of static and kinetic friction between block 1 and the inclined plane are $\mu_s = 0.109$ and $\mu_k = 0.086$, respectively. If the blocks are released from rest, what is the displacement of block 2 in the vertical direction after 1.51 s? Use positive numbers for the upward direction and negative numbers for the downward direction.