GENERALPHYSICS 1

PHYS 110

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Coordinator

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Read the book

Think!

Ask questions

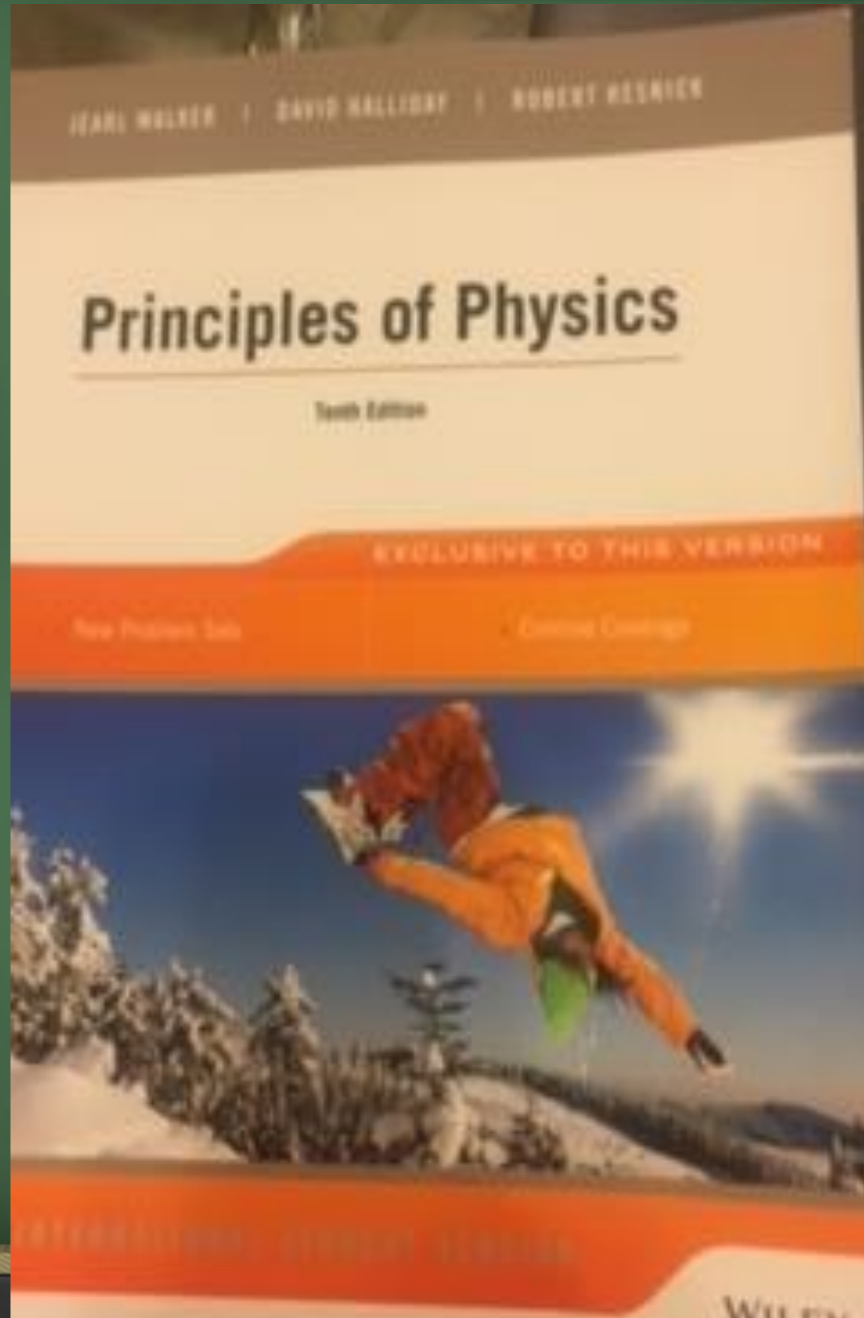
Attend the section

Information is key

No pain no gain ☺

Important Information

- توزيع الدرجات:
  الدوري الاول 30 درجه + 3 درجات بونس (الفصول 1-2-3)
  نصفي 30 درجه + 3 درجات بونس (الفصول 4-5-6)
  النهائي 40 درجه + 4 درجات بونس (جميع الفصول)
- مواعيد الاختبارات وأماكنها تحدد لاحقاً من قبل الشؤون التعليميه وستعلن في موقع المنسقه في حينه
- نظام الحضور والغياب هو نفس نظام الجامعه
- المنسقه/ د. ريم درويش (*rdarwesh.kau.edu.sa*)


JEARL WALKER | DAVID HALLIDAY | ROBERT RESNICK
Principles of Physics
Tenth Edition
EXCLUSIVE TO THIS VERSION
WILEY

ماذا سندرس في منهج فيزياء 110؟

- المنهج هو عبارة عن علم الميكانيكا.

- ما هو علم الميكانيكا؟

علم الميكانيكا علم يختص بدراسة حركة الأجسام والقوى المسببة لها.

Chapter 1
Measurements

By PresenterMedia.com

Physical Quantities

Physics is based on measurement of **Physical Quantities.**

For example: length, time, mass, temperature, pressure.

Physical Quantities

Base quantities

Assumed to be independent of each other.

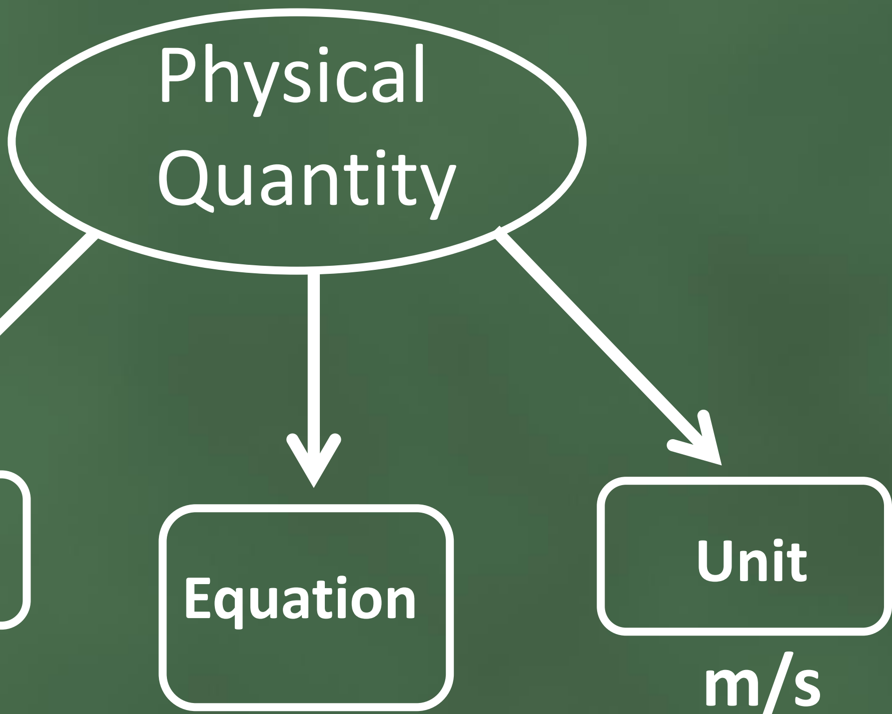
Length, mass and time.

Derived quantities

Defined in terms of base quantities via equations.

$$\text{Velocity} = \frac{\text{Length}}{\text{Time}}$$

Physical Quantities



Velocity : V m/s

V= Length/time

The International System of Units (SI)

Based on the General Conference on Weight and Measurements In 1971.

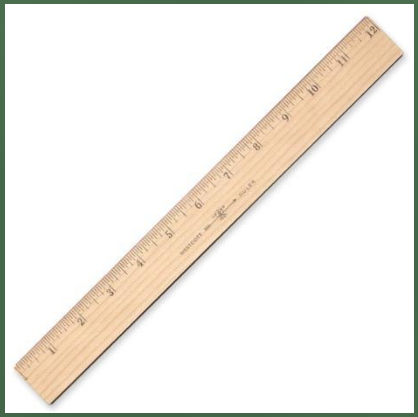
Base Quantities

Units of base quantities

Standards of base quantities

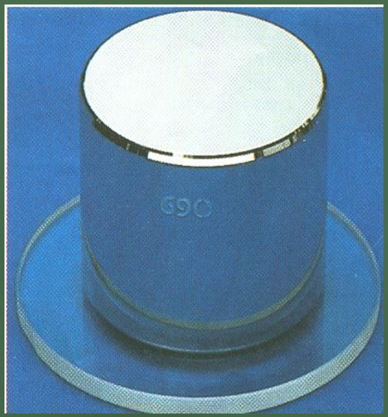
Physical Quantity	Name of Unit	Abbreviation
Mass	*Kilogram*	*Kg*
Length	*Meter*	*m*
Time	*Second*	*s*

Standards of Base Quantities



Length:
A meter is the length of the path traveled by Light in a vacuum during a time interval of 1/299792458 of a second.

Time:
A Second is the time taken by 9192631770 oscillations of the light (of specified wavelength) emitted by cesium-133 atom.



Mass:
A kilogram is the mass of a paltinum-irradium cylinder 3.9 cm in height and diameter kept near Paris.

Scientific Notations

For large or small numbers

- 3560000000.0 m = $3.56 \times 10^{+9}$ m
- 0.00000492 s = 4.92×10^{-6} s

Scientific Notations

- Example

Express 0.00592 in scientific notation.

a) 5.92×10^{3}
b) 5.92×10^{-3}
c) 5.92×10^{-2}
d) 5.92×10^{-5}
e) 5.92×10^{5}

Scientific Notations

- Example

Express 0.00592 in scientific notation.

a) 5.92×10^{3}

b) $\boxed{5.92 \times 10^{-3}}$

c) 5.92×10^{-2}

d) 5.92×10^{-5}

e) 5.92×10^{5}

Scientific Notations

Using prefixes

3.56×10^{9} m giga → G 3.56 Gm

4.92×10^{-6} s $= 4.92\ \mu$ s

Prefixes for SI Units

Factor	Prefix[a]	Symbol
10^{24}	yotta-	Y
10^{21}	zetta-	Z
10^{18}	exa-	E
10^{15}	peta-	P
10^{12}	tera-	T
10^{9}	**giga-**	**G**
10^{6}	**mega-**	**M**
10^{3}	**kilo-**	**k**
10^{2}	hecto-	h
10^{1}	deka-	da
10^{-1}	deci-	d
10^{-2}	**centi-**	**c**
10^{-3}	**milli-**	**m**
10^{-6}	**micro-**	**μ**
10^{-9}	**nano-**	**n**
10^{-12}	**pico-**	**p**
10^{-15}	femto-	f
10^{-18}	atto-	a
10^{-21}	zepto-	z
10^{-24}	yocto-	y

[a]The most frequently used prefixes are shown in bold type.

Conversion between units

Chain-link conversion

Convert 2 min to *s*?

$$\boxed{1\text{min} = 60s}$$

$$\frac{\cancel{1\text{min}}}{\cancel{1\text{min}}} = \frac{60\,s}{1\,\text{min}}$$

$$\Rightarrow \quad 1 = \frac{60s}{1\text{min}}$$

~~$1 = \frac{60}{1}$~~

<u>Conversion factor:</u>
is the ratio of units
that equal unity

$$2\,\cancel{\text{min}} \times \frac{60\text{s}}{1\cancel{\text{min}}} = 120\,\text{s}$$

1. ايجاد العلاقة بين الوحدات المراد تحويلها.
2. نقسم على الوحدة المراد التخلص منها.
3. نختصر و نوجد معامل التحويل المساوي للواحد.
4. نضرب الكمية المراد تحويلها بمعامل التحويل.
5. نختصر و نبسط النتيجة.

Unit Conversion

- Example

Convert 2 *s* to min?

a) 120 min
b) $0.333 \text{x } 10^2$ min
c) 60 min
d) 3.33×10^{-2} min

Unit Conversion

- Example

Convert 2 *s* to min?

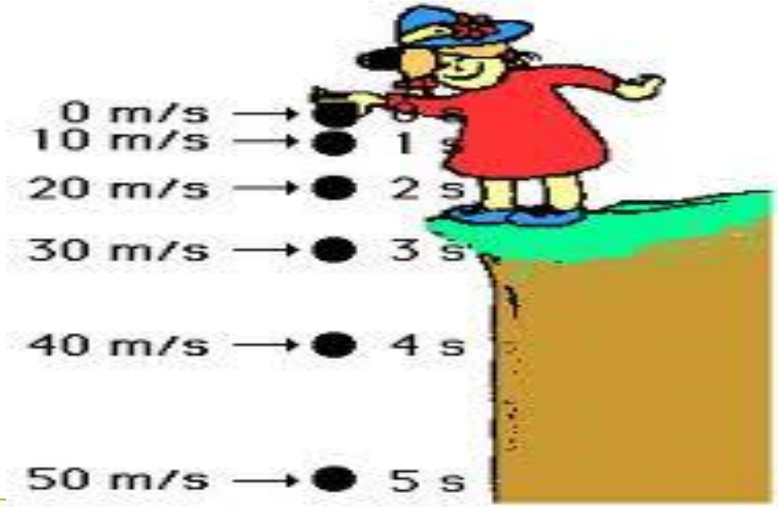
a) 120 min
b) $0.333 x\ 10^{2}$ min
c) 60 min
d) $\boxed{3.33 \times 10^{-2}\ \text{min}}$

Objectives

After this lecture you should be able to...

- Differentiate → Between base and derived quantities
- Explain → Standards of measurements
- Define → The International system of units
- Convert → Units using the chain-link method
- Apply → The scientific notation to numbers

The End



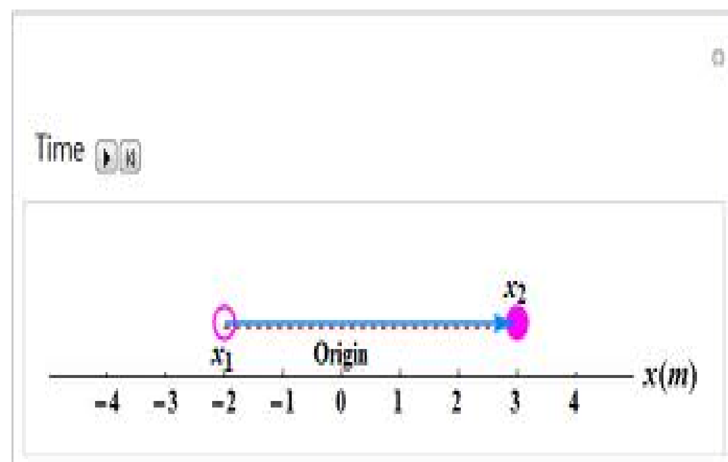
Chapter 2
Motion Along a Straight Line

By: Dr Wajood Diery

$$\Delta d = v_1 t + \frac{1}{2}at^2$$

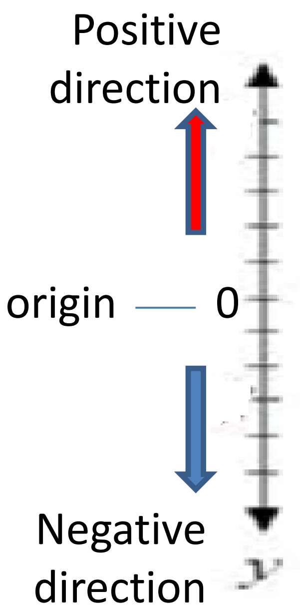
$$v_2 = v_1 + at$$

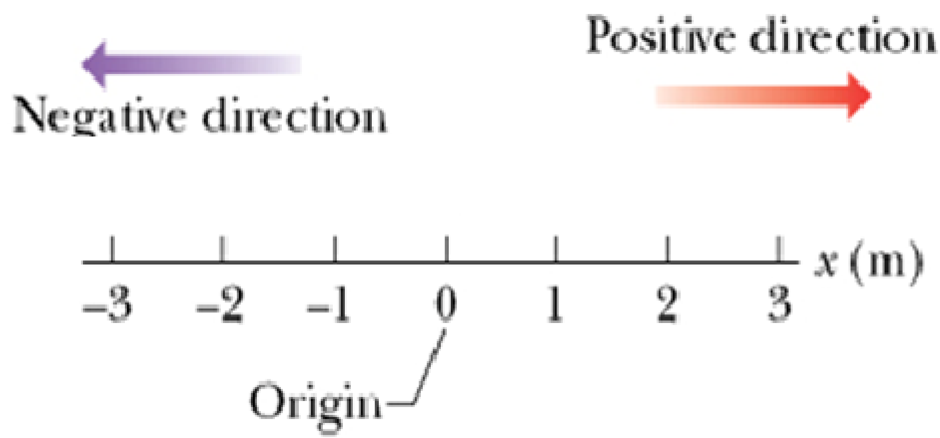
$$v_2^2 = v_1^2 + 2a(\Delta d)$$



2-1 position and displacement, And Average Velocity

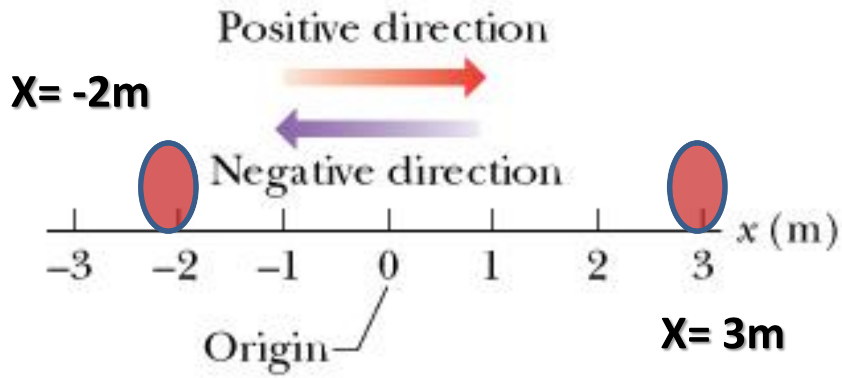
To locate an object means to find it's position relative to reference point origin (or zero point) of an axis .





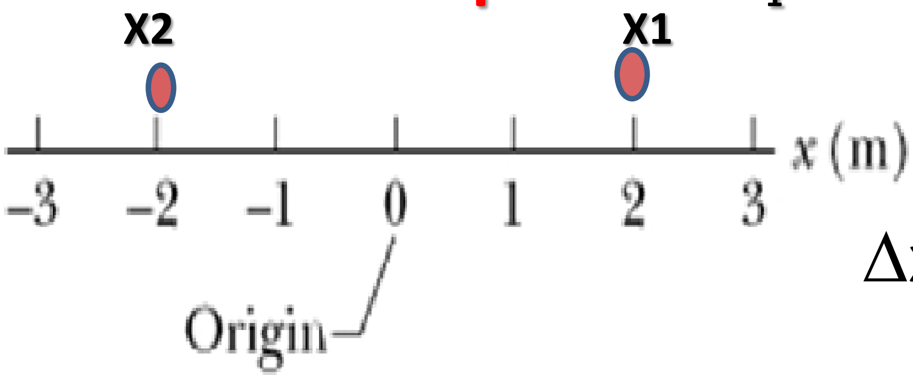
position and displacement

- Position: x
- Unit: m.



position and displacement

If the particle move from the position x_1 to the position x_2



$\Delta X=(-2)-(2)=-4m$

Δx = 4m to the left

Displacement : $\Delta x = x_2 - x_1$

- **Unit: m.**
- **It is a vector quantity: has magnitude and direction.**
- **Direction: if Δx is positive $\Rightarrow$ moving to the right**
  if Δx is negative $\Rightarrow$ moving to the left

Distance : d

It is a scalar quantity: has no direction.

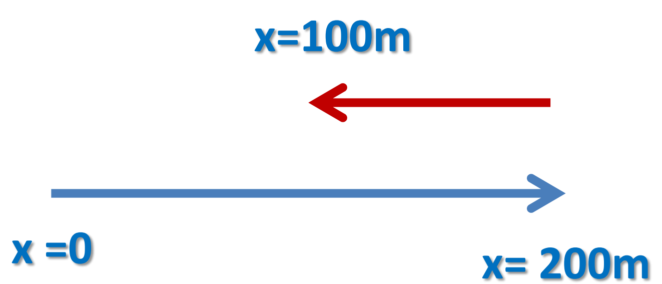
What is the difference between displacement and distance?

if a particle moves from x =0 m to x= 200m and then back to x=100m

$d = 200+100=300$ m

$\Delta x = 100 - 0 = 100$ m

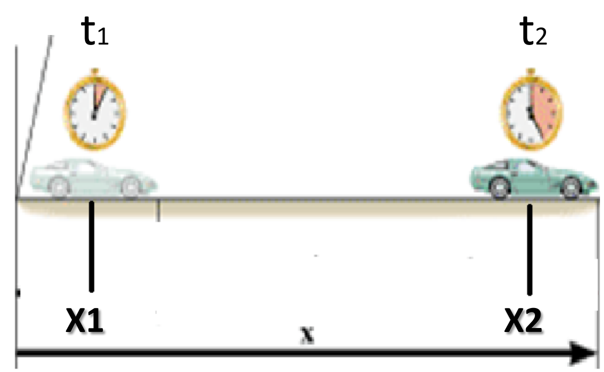
To the right



Average velocity and average speed

Average velocity

- The ratio of displacement that occurs during a particular time interval to that interval.
- $$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$



- Unit of is m/s.
- v_{avg} is a vector quantity.

  - if it is positive $\Rightarrow$ moving to the right
    if it is negative $\Rightarrow$ moving to the left

Average velocity and average speed

Average speed S_{avg}

- The ratio of total distance that occurs during a particular time interval to that interval

- $$S_{avg} = \frac{\text{total distance}}{\Delta t}$$

- Unit of S_{avg} is m/s

- s_{avg} is a scalar quantity

Sample Problem 2.01

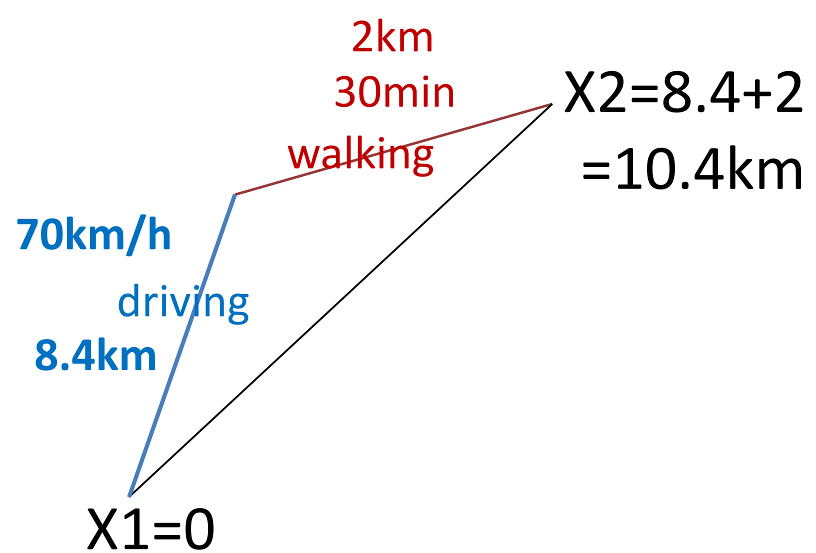
You drive a beat-up pickup truck along a straight road for 8.4 km at 70 km/h, at which point the truck runs out of gasoline and stops. Over the next 30 min, you walk another 2.0 km farther along the road to a gasoline station.

(a) What is your overall displacement from the beginning of your drive to your arrival at the station?

$$\Delta x = x_2 - x_1$$

$$= 10.4-0$$

$$=10.4\text{km}$$



(b) What is the time interval Δt from the beginning of your drive to your arrival at the station?

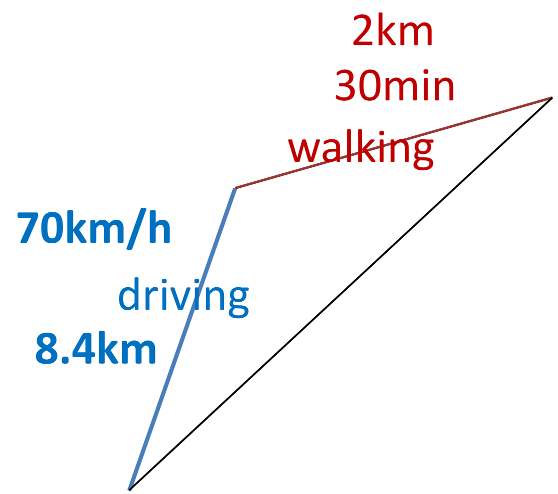
$$\Delta t_{tot} = \Delta t_{drv} + \Delta t_{walk}$$

$$v_{avg,drv} = \frac{\Delta x_{drv}}{\Delta t_{drv}}$$

$$\Delta t_{drv} = \frac{\Delta x_{drv}}{v_{drv}} = \frac{8.4}{70} = 0.12\text{h}$$

$$\Delta t_{walk} = 30\text{min} = 0.5\text{h}$$

$$\Delta t_{tot} = 0.12 + 0.5 = 0.62\text{h}$$

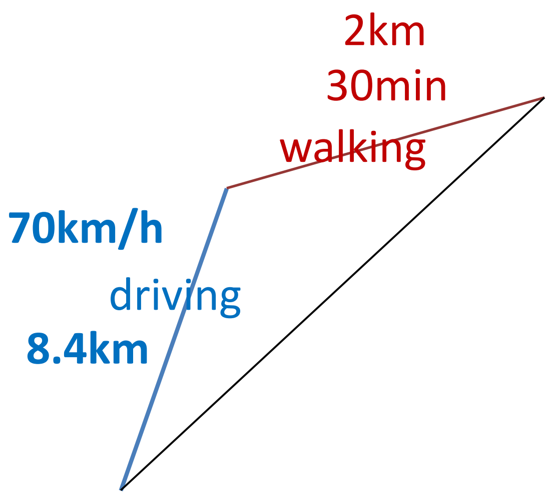


(c) What is your average velocity v_{avg} from the beginning of your drive to your arrival at the station? Find it both numerically and graphically.

$$v_{avg,} = \frac{\Delta x_{tot}}{\Delta t_{tot}}$$

$$= \frac{10.4}{0.62}$$

$$= 17 km/h$$

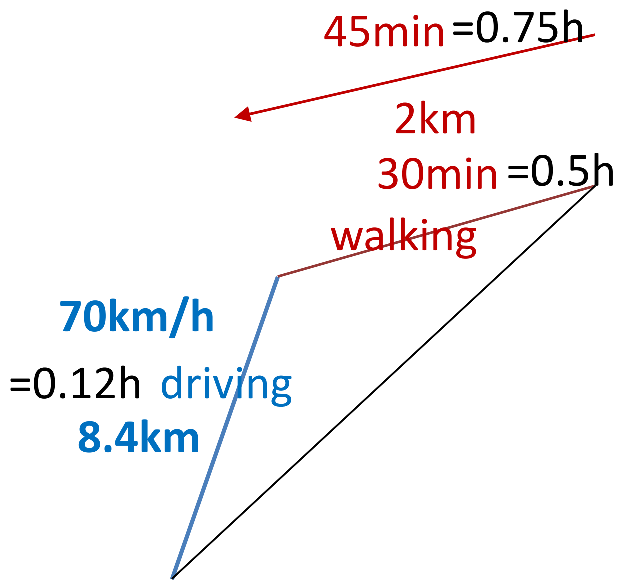


(d) Suppose that to pump the gasoline, pay for it, and walk back to the truck takes you another 45 min. What is your average speed from the beginning of your drive to your return to the truck with the gasoline?

$$s_{avg} = \frac{total\ distance}{total\ time}$$

$$= \frac{8.4 + 2 + 2}{0.12 + 0.5 + 0.75}$$

=9.1km/h



2-2 Instantaneous velocity and speed

Instantaneous velocity *v*

- Velocity at any instant.
- $$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$
- Unit is m/s
- It is a vector quantity

• if v is positive $\Rightarrow$ moving to the right
if v is negative $\Rightarrow$ moving to the left

Instantaneous speed s

- S is the magnitude of velocity

Problem 15 p30

The position of a particle moving on an x axis is given by

$$x = 18t + 0.5t^3$$

With x in meter and t in second.

Calculate a)the instantaneous velocity at t=2s?

Is the velocity constant or is it continuously changing?

$$v = \frac{dx}{dt} = 18 + 0.5\,(3)t^2 = 18 + 1.5t^2$$

$v\ at\ t = 2s$ $\qquad$ $v = 18 + 1.5(2)^2$ =24m/s

the velocity is continuously changing because it depends on time

b) The average velocity between t=2s and t=3s?

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$

$$x = 18t + 0.5t^3$$

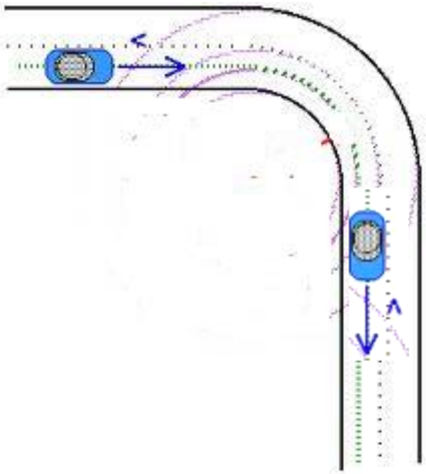
$$at\ t_1 = 2s \ \rightarrow x_1 = 18(2) + 0.5(2)^3 = 40m$$

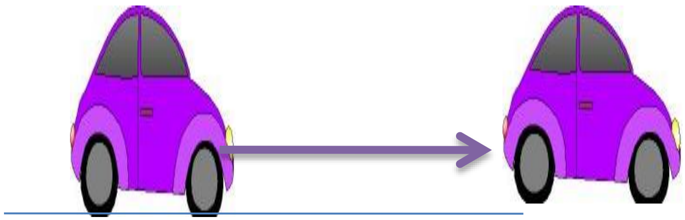
$$at\ t_2 = 3s \ \rightarrow x_2 = 18(3) + 0.5(3)^3 = 67.5m$$

$$v_{avg} = \frac{67.5 - 40}{3 - 1} = 27.5m/s$$

2-3 Acceleration

When an object's velocity changes (**magnitude, or direction**),We say the particle undergoes an acceleration.



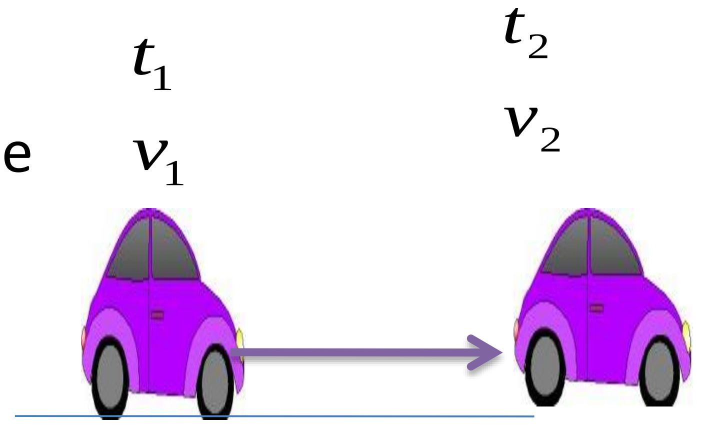


Average Acceleration

Instantaneous Acceleration

Average Acceleration

- is the ratio of a change in velocity to the time Interval in which the change occurs.
- $$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1}$$
- $$\text{Unit : m/s}^2$$
- It is a vector quantity.



Instantaneous Acceleration

- $$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$
- $\text{Unit}: \mathrm{m/s^2}$
- It is a vector quantity.
- $$a = \frac{dv}{dt} \qquad \text{but} \qquad v = \frac{dx}{dt}$$

$$a = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2}$$

$$a$$

$$\frac{dv}{dt} \qquad\qquad \frac{d^2x}{dt^2}$$

Sample Problem 2.03 Acceleration and dv/dt

A particle's position on the x axis of Fig. 2-1 is given by

$$x = 4 - 27t + t^3,$$

with x in meters and t in seconds.

(a) Because position x depends on time t, the particle must be moving. Find the particle's velocity function $v(t)$ and acceleration function $a(t)$.

$$v = \frac{dx}{dt} = 0 - 27 + 3t^2 \qquad v = -27 + 3t^2$$

$$a = \frac{dv}{dt} = 0 + (3)(2)t = 6t$$

(b) Is there ever a time when $v = 0$?

$$v = -27 + 3t^2$$

$$t = ???\quad v = 0 \rightarrow 0 = -27 + 3t^2 \qquad t = +3s$$

To the left

downward

upward

To the right

Motion In negative direction	Motion In positive direction
Velocity increase a -ve	**Velocity increases** a +ve
Velocity decreases a +ve	**Velocity decrease** a -ve

2-4 Constant acceleration

☞ **Constant acceleration does not mean the velocity is constant, it means the velocity changes with constant rate.**

☞ **Constant acceleration does not mean a=0.**
If a=0 $\Rightarrow$ v is constant.

Equations of motion

Equation
$v = v_0 + at$
$x - x_0 = v_0 t + \frac{1}{2} a t^2$
$v^2 = v_0^2 + 2a(x - x_0)$
$x - x_0 = \frac{1}{2}(v_0 + v)t$
$x - x_0 = vt - \frac{1}{2} a t^2$

$x_0 \rightarrow$ Initial position

$x \rightarrow$ final position

$x - x_0 \rightarrow$ displacment

$v_0 \rightarrow$ Initial velocity

$v \rightarrow$ final velocity

$t \rightarrow$ time

$a \rightarrow$ Constant acceleration

- when the object starts from rest $\boxed{\Rightarrow v_0 = 0}$
- when the object stops $\boxed{\Rightarrow v = 0}$
- $x_0 = 0$ unless something else mentioned in the problem.

Problem Page 30

25 A particle confined to motion along an x axis moves with $\boxed{\text{constant acceleration}}$ from $x = 2.0$ m to $x = 8.0$ m during a 2.5 s time interval. The velocity of the particle at $x = 8.0$ m is 2.8 m/s. What is the constant acceleration during this time interval?

$x_o = 2m \quad x = 8m \quad t = 2.5s \quad v = 2.8m/s$

$a = ??$

$$x - x_0 = vt - \frac{1}{2}at^2$$

$$8 - 2 = (2.8)(2.5) - \frac{1}{2}a(2.5)^2$$

$$a = 0.32m/s^2$$

$$v = v_0 + at$$

$$x - x_0 = v_0 t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$x - x_0 = \frac{1}{2}(v_0 + v)t$$

$$x - x_0 = vt - \frac{1}{2}at^2$$

Problem Page 30

27 An electron, starting from rest and moving with a $\boxed{\text{constant acceleration}}$, travels 2.00 cm in 5.00 ms. What is the magnitude of this acceleration?

$$from\ rest\ \ v_o = 0$$

$$v = v_0 + at$$

$$x_o = 0\ \ x = 2cm = 0.02m\ \ t = 5ms = 0.005s$$

$$x - x_0 = v_0 t + \frac{1}{2}at^2$$

$$a = ??$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$x - x_0 = v_0 t + \frac{1}{2}at^2$$

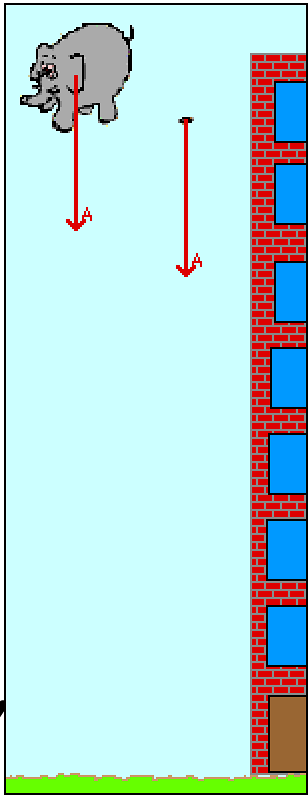
$$0.02 - 0 = 0(0.005) + \frac{1}{2}a(0.005)^2$$

$$x - x_0 = \frac{1}{2}(v_0 + v)t$$

$$x - x_0 = vt - \frac{1}{2}at^2$$

$$a = 1600m/s^2$$

2-5 Free fall acceleration



- Free fall is the motion of an object under influence of Gravity and ignoring any other effects such as air resistance.

- All objects in free fall accelerate downward at the same rate and it is independent of the object's mass, density or shape.

- This acceleration is called **the free-fall acceleration**.

- $\boxed{g = 9.8 m/s^2 \quad downward}$

Equations of motion

- The motion along y axis $x \rightarrow y$
- $a = -g$

$$v = v_0 + at \quad \rightarrow$$

$$x - x_0 = v_0 t + \frac{1}{2} a t^2 \quad \rightarrow$$

$$v^2 = v_0^2 + 2a(x - x_0) \quad \rightarrow$$

$$x - x_0 = \frac{1}{2}(v_0 + v)t \quad \rightarrow$$

$$x - x_0 = vt - \frac{1}{2} a t^2 \quad \rightarrow$$

$$v = v_0 - gt$$

$$y - y_0 = v_0 t - \frac{1}{2} g t^2$$

$$v^2 = v_0^2 - 2g(y - y_0)$$

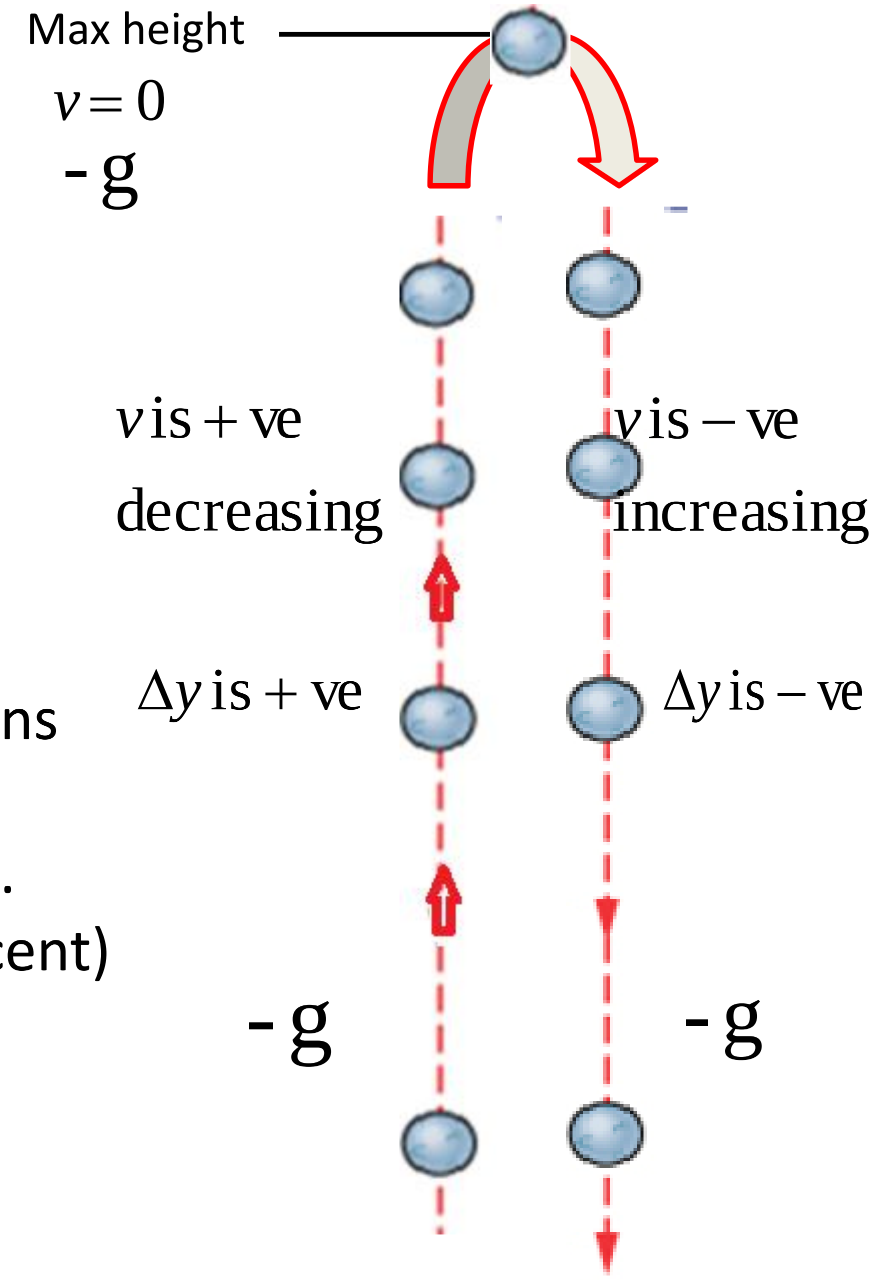
$$y - y_0 = \frac{1}{2}(v_0 + v)t$$

$$y - y_0 = vt + \frac{1}{2} g t^2$$

- When substituting for g in the equations

g = 9.8m/s.

- when the object is moving up (ascent).
- When the object is moving down (descent)



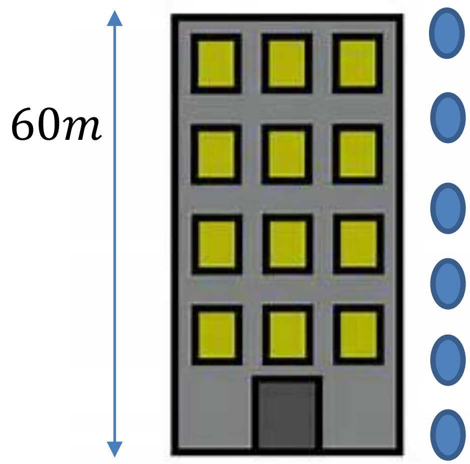
33 A stone is thrown from the top of a building with an initial velocity of 20 m/s downward. The top of the building is 60 m above the ground. How much time elapses between the instant of release and the instant of impact with the ground?

$v_o = -20m/s \quad y_o = 0 \quad y = -60m \quad$ g= $9.8m/s^2 \qquad t = ??$

$$y - y_0 = v_0 t - \frac{1}{2} g t^2$$

$$-60 - 0 = -20t - \frac{1}{2}(9.8)t^2$$

$$t = 2s$$



$$v = v_0 - gt$$

$$y - y_0 = v_0 t - \frac{1}{2} g t^2$$

$$v^2 = v_0^2 - 2g(y - y_0)$$

$$y - y_0 = \frac{1}{2}(v_0 + v)t$$

$$y - y_0 = vt + \frac{1}{2} g t^2$$

Sample Problem 2.05 Time for full up-down flight, baseball toss

In Fig. 2-13, a pitcher tosses a baseball up along a y axis, with an initial speed of 12 m/s.

(a) How long does the ball take to reach its $\boxed{\text{maximum height}}$?

$v = 0 \qquad v_0 = 12m/s \qquad g = 9.8m/s^2 \qquad t = ??$

$$v = v_0 - gt$$

$0 = 12 - (9.8)t \qquad t = 1.2s$

(b) What is the ball's maximum height above its release point?

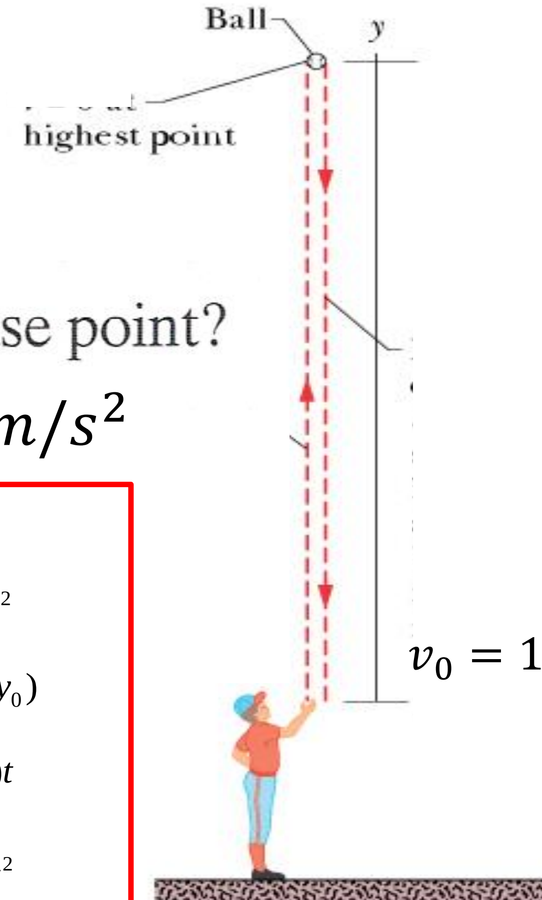
$y = ?? \qquad y_o = 0 \qquad v = 0 \qquad v_0 = 12m/s \qquad g = 9.8m/s^2$

$$v^2 = v_0^2 - 2g(y - y_0)$$

$$0 = (12)^2 - 2(9.8)(y - 0)$$

$$y = 7.3m$$

$$\boxed{\begin{aligned} v &= v_0 - gt \\ y - y_0 &= v_0 t - \frac{1}{2}gt^2 \\ v^2 &= v_0^2 - 2g(y - y_0) \\ y - y_0 &= \frac{1}{2}(v_0 + v)t \\ y - y_0 &= vt + \frac{1}{2}gt^2 \end{aligned}}$$



(c) How long does the ball take to reach a point 5.0 m above its release point?

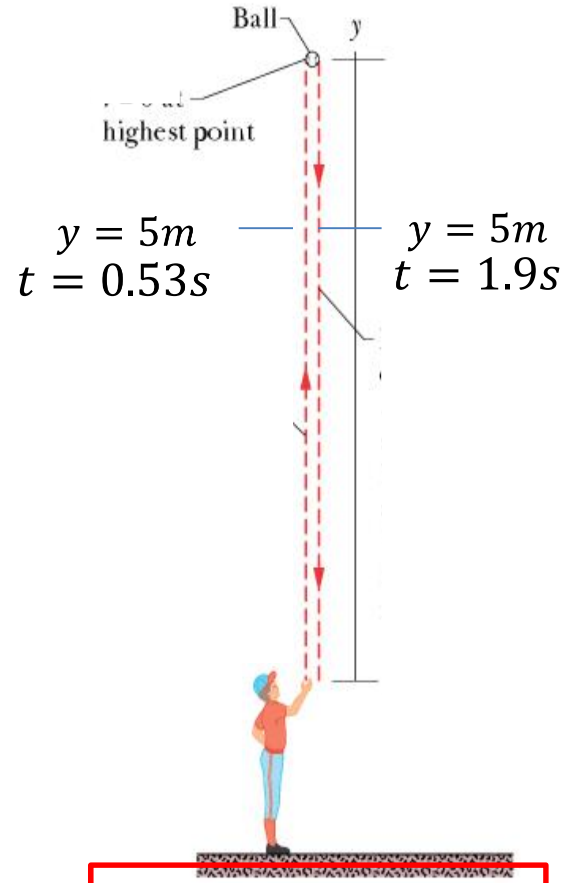
$y = 5m \quad y_o = 0 \quad v_0 = 12 m/s \quad g = 9.8 m/s^2$

$t = ??$

$$y - y_0 = v_0 t - \frac{1}{2} g t^2$$

$$5 - 0 = 12t - \frac{1}{2}(9.8)t^2$$

$t = 0.53 \qquad t = 1.9$



$$v = v_0 - gt$$

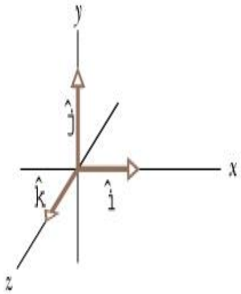
$$y - y_0 = v_0 t - \frac{1}{2} g t^2$$

$$v^2 = v_0^2 - 2g(y - y_0)$$

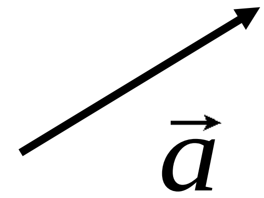
$$y - y_0 = \frac{1}{2}(v_0 + v)t$$

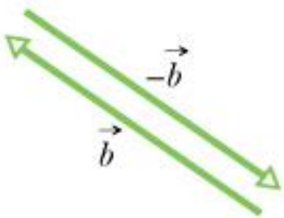
$$y - y_0 = vt + \frac{1}{2} g t^2$$

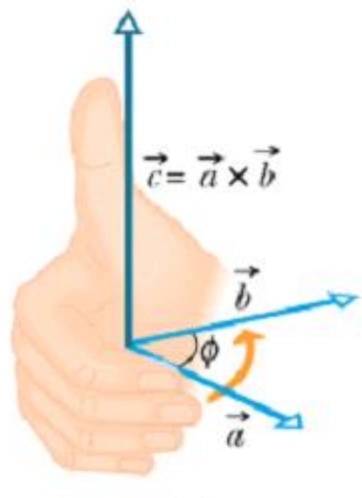

THE
END



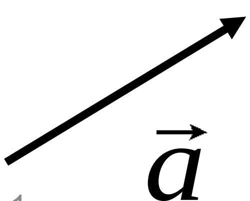
Chapter 3







VECTORS



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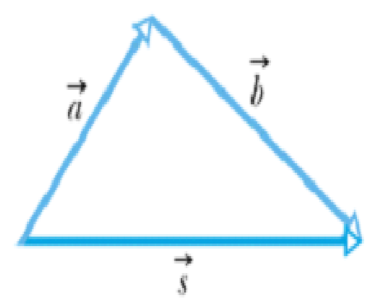


3-1 VECTORS AND THEIR COMPONENTS

Vectors and Scalars

Physical Quantities

Vector Quantities

magnitude + direction

Follow certain rules of addition and multiplication

Scalar Quantities

+Ve Number

-Ve Number

Follow the rules of ordinary algebra

Vectors

Adding Vectors

Geometrically

- Adding vectors.
- Commutative Law.
- Associative Law.
- Vector Subtraction.

By Components

- resolving a vector.
- unit vectors.
- Adding vectors.

Multiplying Vectors

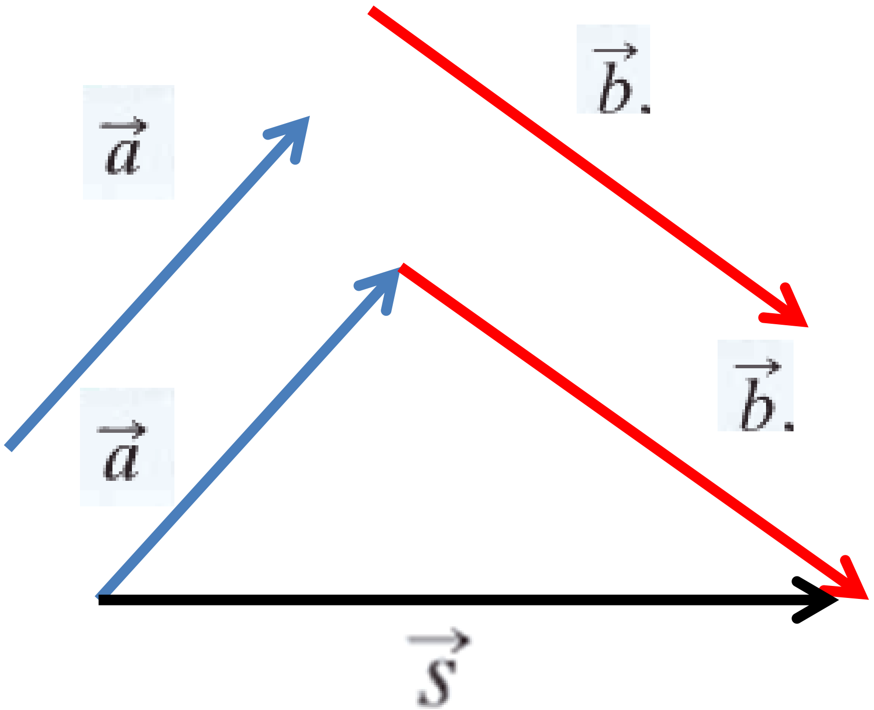
By scalar

By a vector

- Scalar Product
- vector Product

Adding Vectors Geometrically

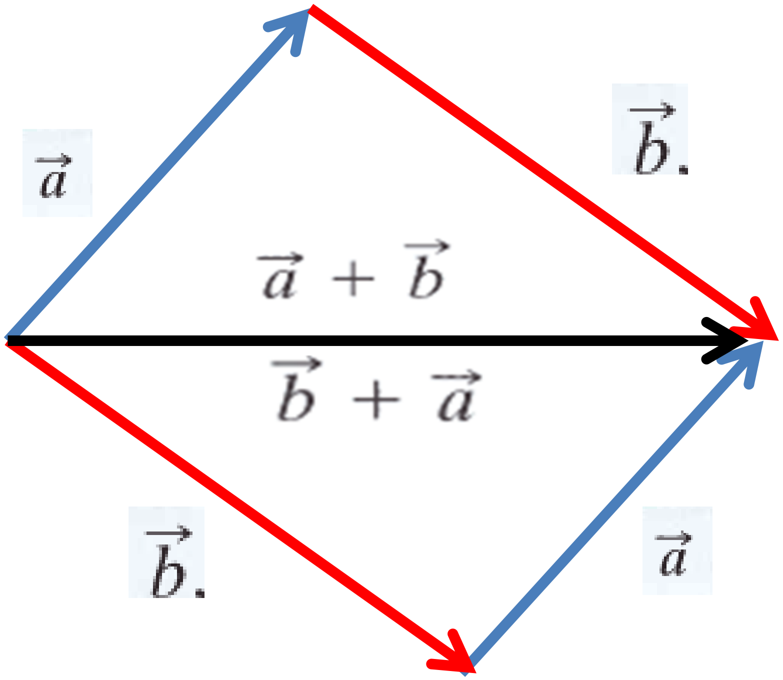
- Draw the first vector.
- From the end of the first vector draw the second vector.
- And so on.
- Draw a line from the start point to the end point and this will be the Sum or resultant.



- Vector equation

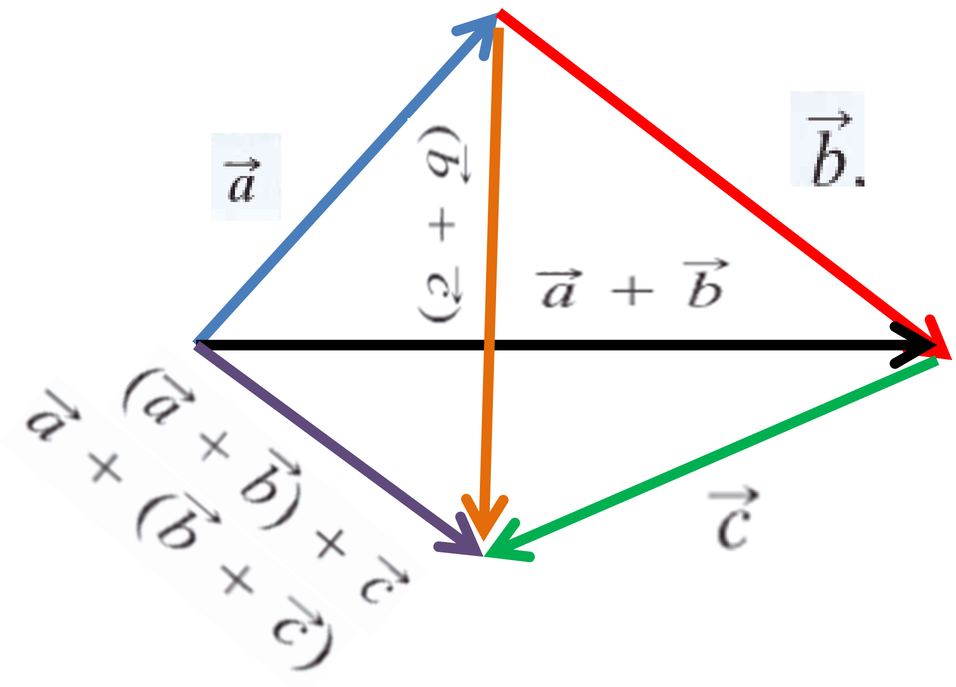
$$\vec{s} = \vec{a} + \vec{b},$$

• Commutative Law



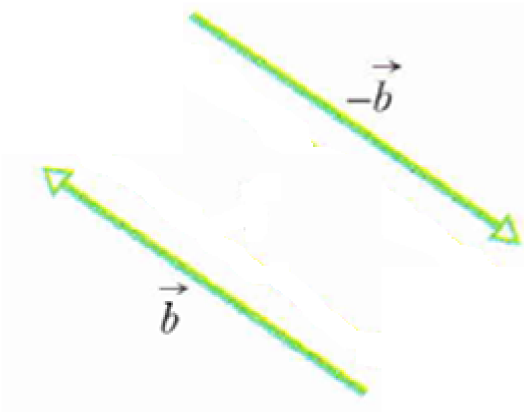
$$\vec{a} + \vec{b} = \vec{b} + \vec{a}$$

• Associative Law

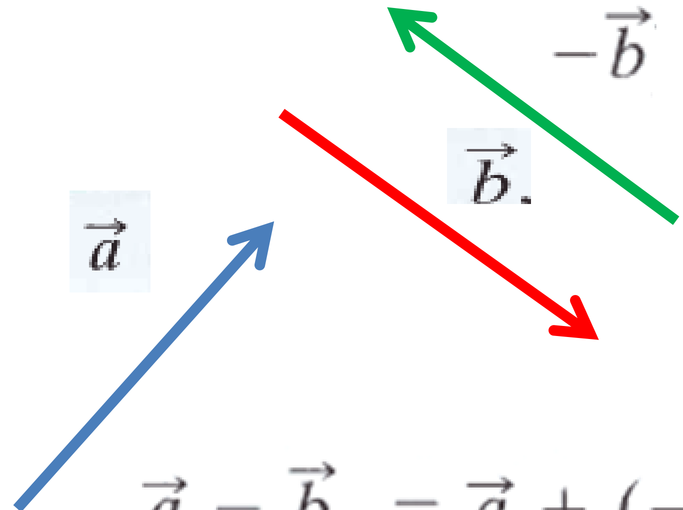


$$(\vec{a} + \vec{b}) + \vec{c} = \vec{a} + (\vec{b} + \vec{c})$$

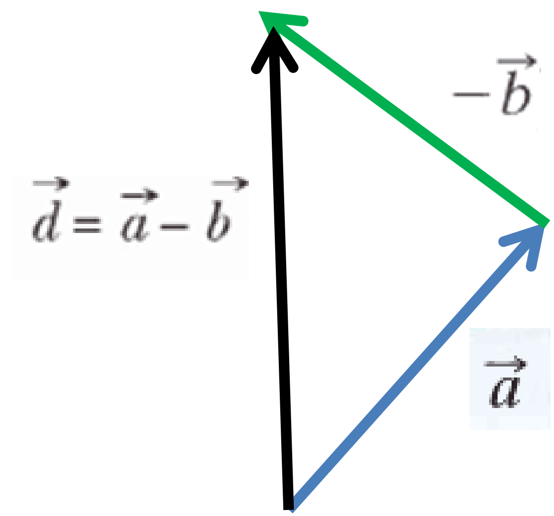
• Vector Subtraction



$$\vec{b} + (-\vec{b}) = 0.$$



$$\vec{a} - \vec{b} = \vec{a} + (-\vec{b})$$

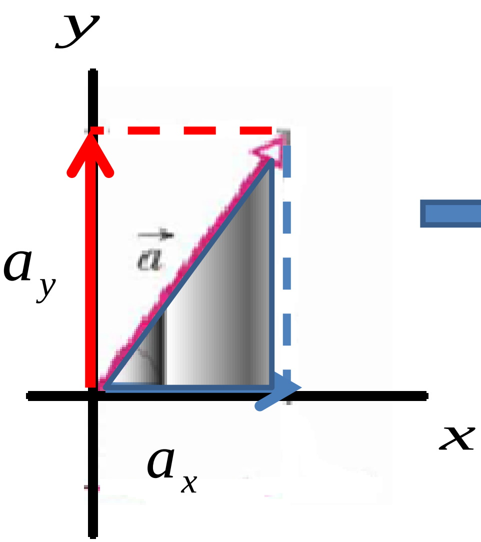


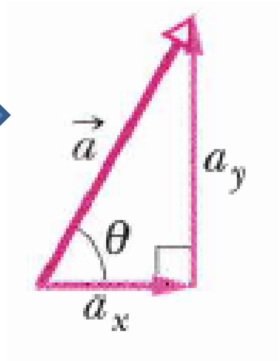
$$\boxed{\vec{d} = \vec{a} - \vec{b} = \vec{a} + (-\vec{b})}$$

Components of Vectors

- Resolving the vector is the process of finding the components

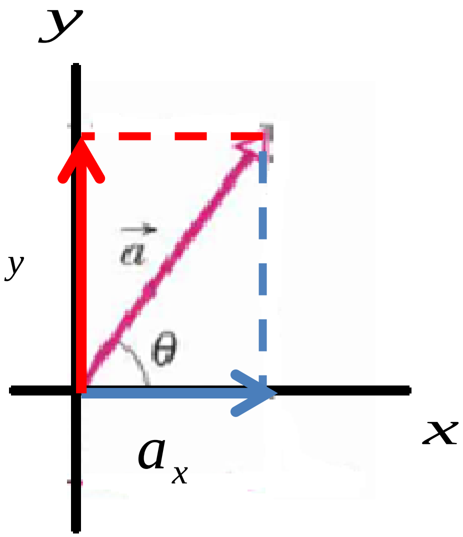
- Component is the projection of the vector on an axis

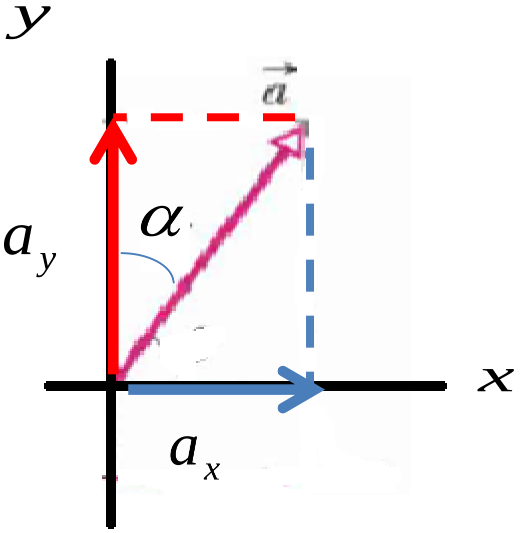




$$\cos\theta = \frac{a_x}{a} \quad , \quad \sin\theta = \frac{a_y}{a}$$

$$a_x = a\cos\theta \quad \text{and} \quad a_y = a\sin\theta$$





$$a_x = a\cos\theta \text{ and } a_y = a \sin\theta$$

$$a_x = a\sin\alpha \text{ and } a_y = a \cos\alpha$$

- Writing a vector in magnitude- angle notation

$$\vec{a}:\ a_x\ and\ a_y$$

Magnitude

$$\boxed{a\ ,\ |a| = \sqrt{a_x^2 + a_y^2}}$$

Direction (angle)

$$\boxed{\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right)}$$

The angle is measured from positive X-axis.

$$\vec{a}$$

$$a \ and \ \theta$$

- Finding the components.

$$a_x = a\cos\theta$$

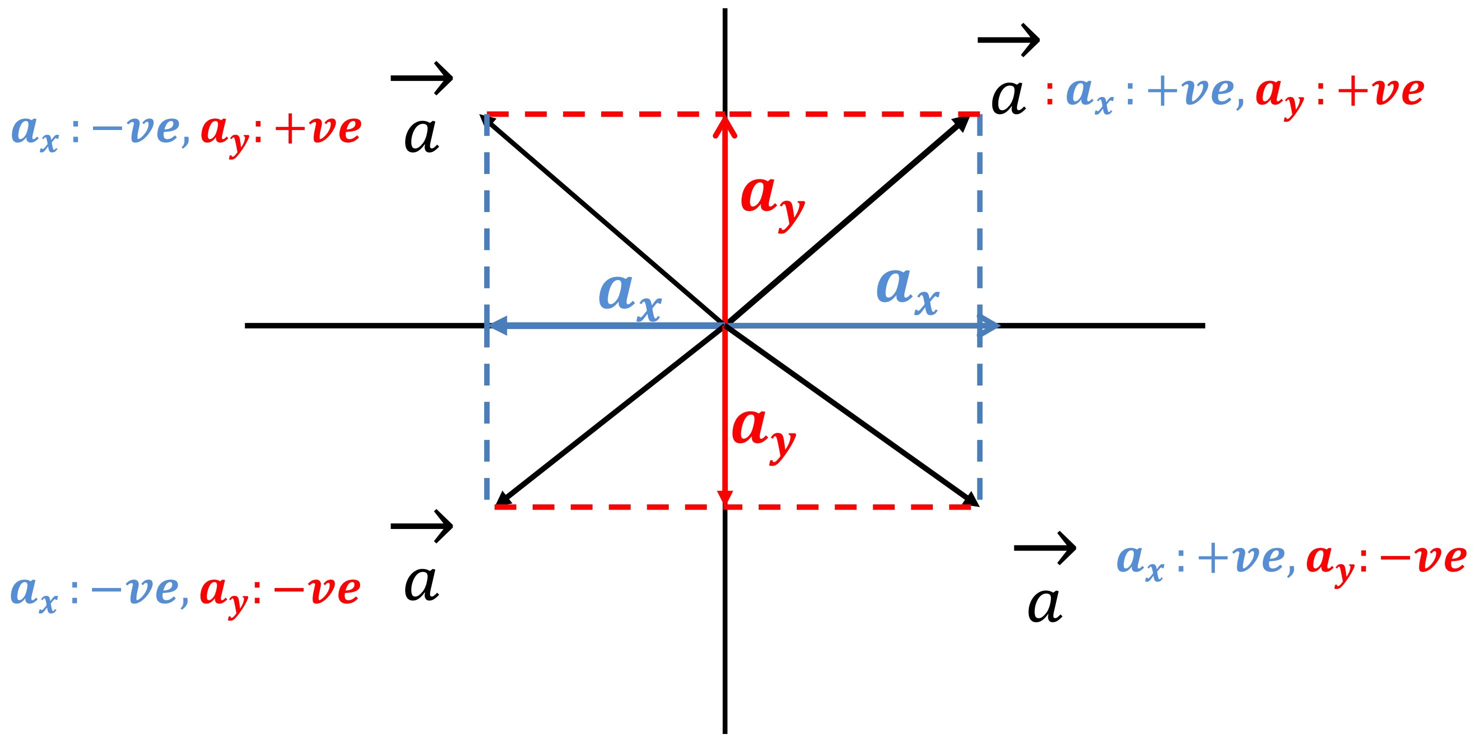
$$a_y = a\sin\theta$$

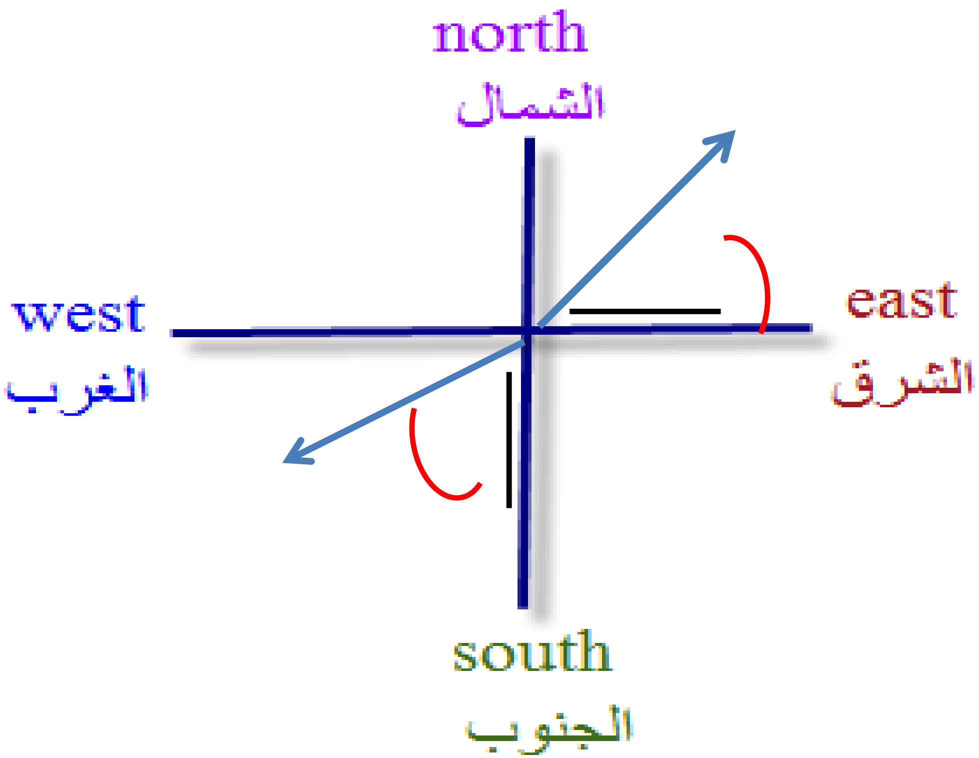
$$a_x \ and \ a_y$$

- Writing a vector in magnitude-angle notation

$$a = \sqrt{a_x^2 + a_y^2}$$

$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right)$$


$\vec{a}$: a_x : $+ve$, a_y : $+ve$
a_x : $-ve$, a_y : $+ve$ $\vec{a}$
a_y
a_x
a_x
a_y
a_x : $-ve$, a_y : $-ve$ $\vec{a}$
$\vec{a}$ a_x : $+ve$, a_y : $-ve$



North of east

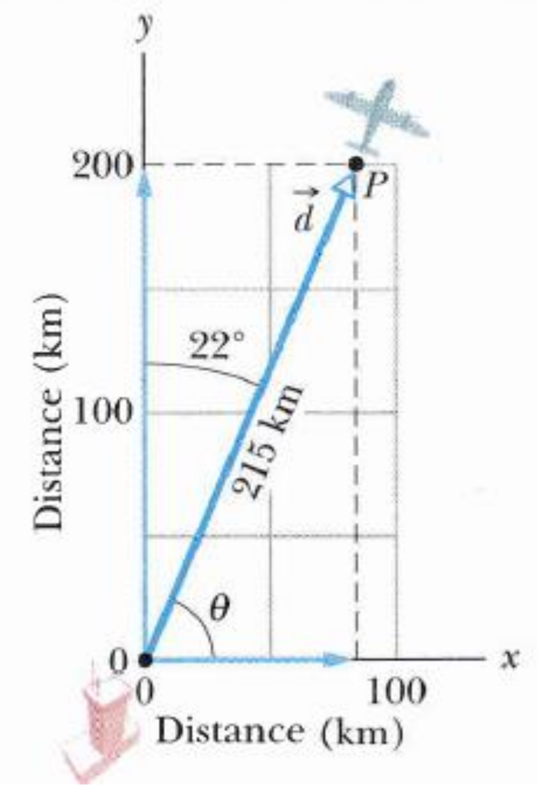
West of south

Sample Problem 3.02

A small airplane leaves an airport on an overcast day and is later sighted 215 km away, in a direction making an angle of 22° east of due north. How far east and north is the airplane from the airport when sighted?

$$d_x = d\cos\theta = (215\text{ km})(\cos 68°)$$
$$= 81\text{ km}$$

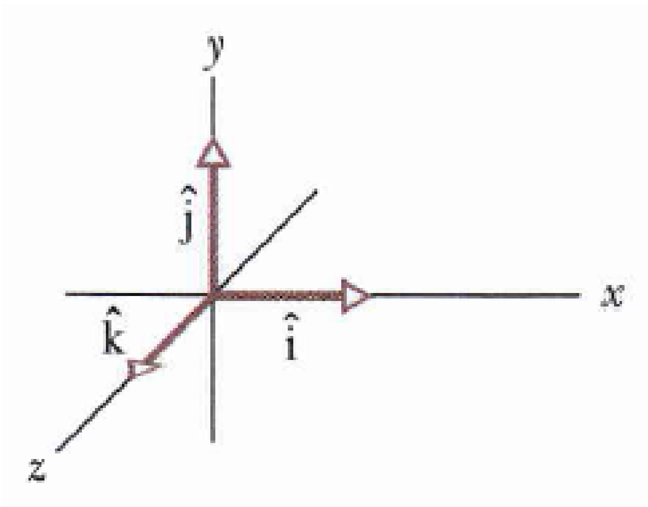
$$d_y = d\sin\theta = (215\text{ km})(\sin 68°)$$
$$= 199\text{ km} \approx 2.0 \times 10^2\text{ km}.$$



3-2 UNIT VECTORS, ADDING VECTORS BY COMPONENT

Unit Vectors

- Unit vector is a vector of magnitude 1 and points in a particular direction



- **Writing a vector in Unit vector notation**

$$\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$$

Vector Components

$$\vec{a} = \boxed{a_x\hat{i}} + \boxed{a_y\hat{j}} + \boxed{a_z\hat{k}}$$

Scalar components

Adding vectors by Components

$$\vec{a} = a_x\hat{\imath} + a_y\hat{\jmath} + a_z\hat{k}$$

$$\vec{b} = b_x\hat{\imath} + b_y\hat{\jmath} + b_z\hat{k}$$

$$\vec{r} = \vec{a} \mp \vec{b}$$

$$\vec{r} = r_x\hat{\imath} + r_y\hat{\jmath} + r_z\hat{k}$$

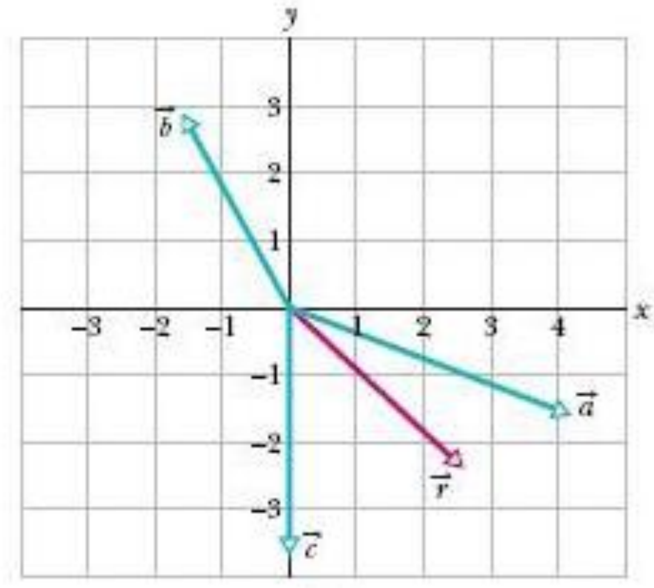
$$r_x = a_x \mp b_x \qquad r_y = a_y \mp b_y \qquad r_z = a_z \mp b_z$$

Sample Problem 3.04

Figure 3-17a shows the following three vectors:

$$\vec{a} = (4.2\text{ m})\hat{\text{i}} - (1.5\text{ m})\hat{\text{j}},$$
$$\vec{b} = (-1.6\text{ m})\hat{\text{i}} + (2.9\text{ m})\hat{\text{j}},$$
and
$$\vec{c} = (-3.7\text{ m})\hat{\text{j}}.$$

What is their vector sum $\vec{r}$ which is also shown?



3-3 MULTIPLYING VECTORS

Multiplying vectors

Multiplying a vector by a scalar

- +ve scalar → will produce a new vector in the same direction as the started vector

$$\vec{a} = 2\hat{\imath} + 3\hat{\jmath}$$

$$2\vec{a} = 4\hat{\imath} + 6\hat{\jmath}$$

- -ve scalar → will produce a new vector in the opposite direction of the started vector

$$\vec{a} = 2\hat{\imath} + 3\hat{\jmath}$$

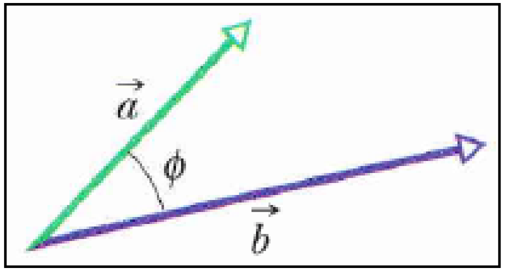
$$-2\vec{a} = -4\hat{\imath} - 6\hat{\jmath}$$

Multiplying a vector by a vector

- **Scalar product (or Dot product)** → will produce a scalar
- **Vector product (or cross product)** → will produce a new vector

Scalar (or Dot product)

If the two vectors are given in magnitude and the angle between them



$$\vec{a} \cdot \vec{b} = ab\cos\phi$$

If the two vectors are given in unit vector notation

$$\vec{a} = a_x\hat{\imath} + a_y\hat{\jmath} + a_z\hat{k}$$

$$\vec{b} = b_x\hat{\imath} + b_y\hat{\jmath} + b_z\hat{k}$$

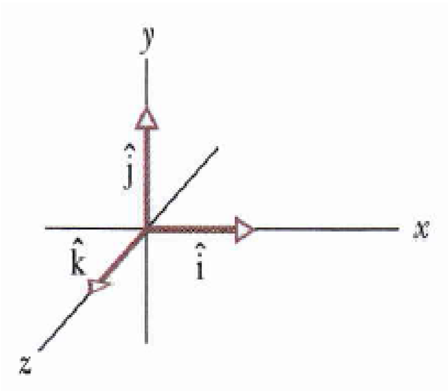
$$\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z$$

$$\boxed{\vec{a}\cdot\vec{b} = ab\cos\phi}$$

- The scalar product is commutative ⇨ $\vec{a}\cdot\vec{b} = \vec{b}\cdot\vec{a}$
- If the two vectors are parallel ⇨ $\theta = 0 \Rightarrow \vec{a}\,.\,\vec{b} = a\,b$
- If the two vectors are perpendicular ⇨ $\theta = 90 \Rightarrow \vec{a}\,.\,\vec{b} = 0$
- If the two vectors are Antiparallel ⇨ $\theta = 180 \Rightarrow \vec{a}\,.\,\vec{b} = -\,a\,b$
- Multiplying Unit vectors

$\hat{i}.\hat{i} = (1)(1)\cos 0 = 1$ ⇨ $\hat{i}\cdot\hat{i} = \hat{j}\cdot\hat{j} = \hat{k}\cdot\hat{k} = 1$

$\hat{i}.\hat{j} = (1)(1)\cos 90 = 0$ ⇨ $\hat{i}\cdot\hat{j} = \hat{j}\cdot\hat{k} = \hat{k}\cdot\hat{i} = 0$



Properties Of the scalar product

The scalar product is commutative

$$\vec{a}\cdot\vec{b}=\vec{b}\cdot\vec{a}$$

the angle between two vectors can be found

$$\vec{a}\cdot\vec{b}=ab\,\cos\theta$$

any two similar unit vectors

$$\hat{i}\cdot\hat{i}=\hat{j}\cdot\hat{j}=\hat{k}\cdot\hat{k}=1$$

any two different unit vectors

$$\hat{i}\cdot\hat{j}=\hat{j}\cdot\hat{k}=\hat{k}\cdot\hat{i}=0$$

If $\theta=0 \Rightarrow \vec{a}\,.\vec{b}=a\,b$ ⇨ vectors are parallel

$\theta=180 \Rightarrow \vec{a}\,.\vec{b}=-\,a\,b$ ⇨ vectors are anti parallel

$\theta=90 \Rightarrow \vec{a}\,.\vec{b}=0$ ⇨ vectors are perpendicular

Sample Problem 3.05

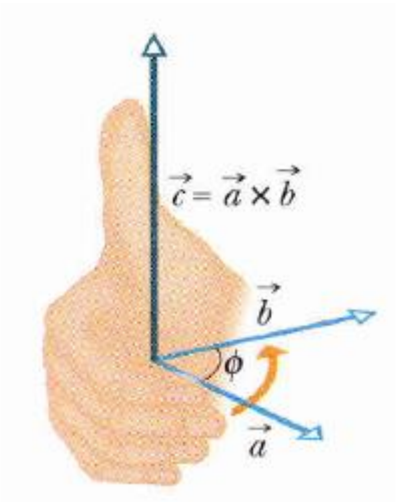
What is the angle ϕ between $\vec{a} = 3.0\hat{\mathrm{i}} - 4.0\hat{\mathrm{j}}$ and $\vec{b} = -2.0\hat{\mathrm{i}} + 3.0\hat{\mathrm{k}}$?

Vector (or Cross product)

If the two vectors are given in magnitude and angle between them

$$|\vec{a} \times \vec{b}| = |c| = ab \sin\phi$$

The direction of the result vector



If the two vectors are given in unit vector notation

$$\vec{a} = a_x\hat{\imath} + a_y\hat{\jmath} + a_z\hat{k}$$

$$\vec{b} = b_x\hat{\imath} + b_y\hat{\jmath} + b_z\hat{k}$$

$$\vec{a} \times \vec{b} = \begin{vmatrix} \hat{\mathrm{i}} & \hat{\mathrm{j}} & \hat{\mathrm{k}} \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$$

$$= \hat{\mathrm{i}} \begin{vmatrix} a_y & a_z \\ b_y & b_z \end{vmatrix} - \hat{\mathrm{j}} \begin{vmatrix} a_x & a_z \\ b_x & b_z \end{vmatrix} + \hat{\mathrm{k}} \begin{vmatrix} a_x & a_y \\ b_x & b_y \end{vmatrix}$$

$$= (a_y b_z - b_y a_z)\hat{\mathrm{i}} + (a_z b_x - b_z a_x)\hat{\mathrm{j}}$$
$$+ (a_x b_y - b_x a_y)\hat{\mathrm{k}}$$

$$\boxed{|\vec{a} \times \vec{b}| = |c| = ab\ \sin\phi}$$

◊ The scalar product is Anti-commutative ➡ $\vec{a} \times \vec{b} = -\vec{b} \times \vec{a}$

◊ If the two vectors are parallel ➡ $\theta = 0 \Rightarrow \vec{a} \times \vec{b} = 0$

◊ If the two vectors are perpendicular ➡ $\theta = 90 \Rightarrow |\vec{a} \times \vec{b}| = a\,b$

◊ If the two vectors are Anti-parallel ➡ $\theta = 180 \Rightarrow \vec{a} \times \vec{b} = 0$

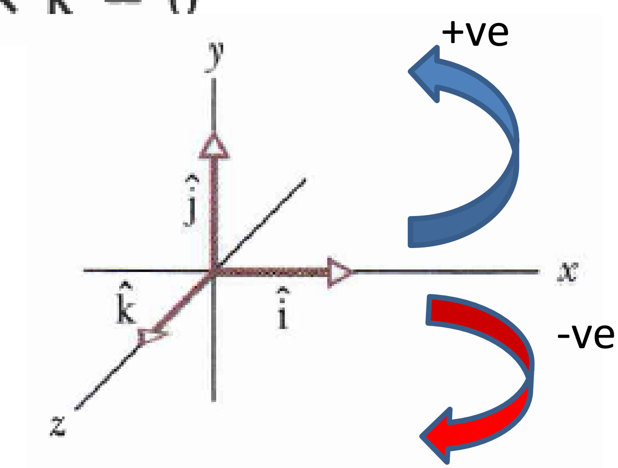
◊ Multiplying Unit vectors

$$\left|\hat{i}.\hat{i}\right| = (1)(1)\sin 0 = 0 \;\Rightarrow\; \hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0$$

$$\left|\hat{i}.\hat{j}\right| = (1)(1)\sin 90 = 1 \;\Rightarrow\; \hat{i}.\hat{j} = \hat{k}$$

$$\hat{i} \times \hat{j} = \hat{k}, \qquad \hat{j} \times \hat{k} = \hat{i}, \qquad \hat{k} \times \hat{i} = \hat{j}$$

$$\hat{j}.\hat{i} = -\hat{k} \qquad \hat{k}.\hat{j} = -\hat{i} \qquad \hat{i}.\hat{k} = -\hat{j}$$



Properties of the Vector product

Anti- commutative

$$\vec{a} \times \vec{b} = -\vec{b} \times \vec{a}$$

any two different unit vectors

$$\hat{i} \times \hat{j} = \hat{k}, \quad \hat{j} \times \hat{k} = \hat{i},$$

$$\hat{k} \times \hat{i} = \hat{j}$$

any two similar unit vectors

$$\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0$$

The small angle between the two vectors must be used because the odd property of the sin function

$$|\vec{a} \times \vec{b}| = |c| = ab \sin\phi$$

If $\theta = 0 \Rightarrow \vec{a} \times \vec{b} = 0$ ⇒ vectors are parallel

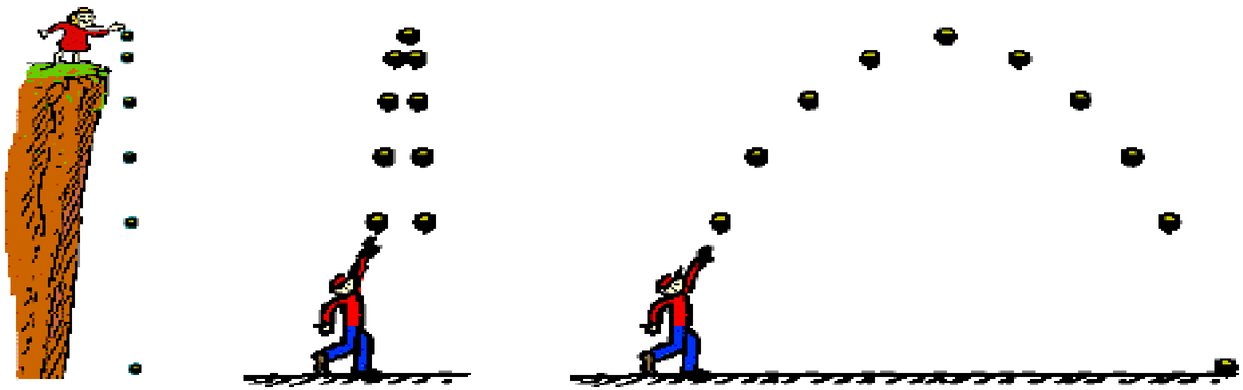
$\theta = 180 \Rightarrow \vec{a} \times \vec{b} = 0$ ⇒ vectors are anti parallel

$\theta = 90 \Rightarrow |\vec{a} \times \vec{b}| = a\,b$ ⇒ vectors are perpendicular

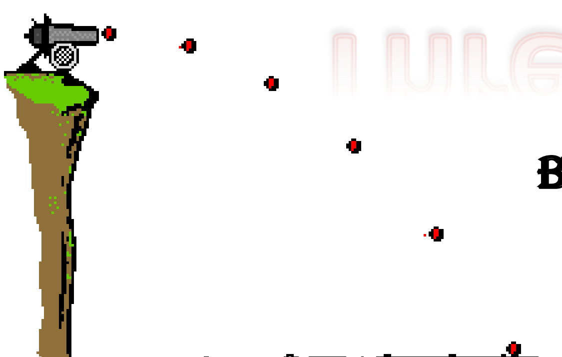
Sample Problem 3.07

If $\vec{a} = 3\hat{i} - 4\hat{j}$ and $\vec{b} = -2\hat{i} + 3\hat{k}$, what is $\vec{c} = \vec{a} \times \vec{b}$?


The End



Motion in Two And Three Dimensions



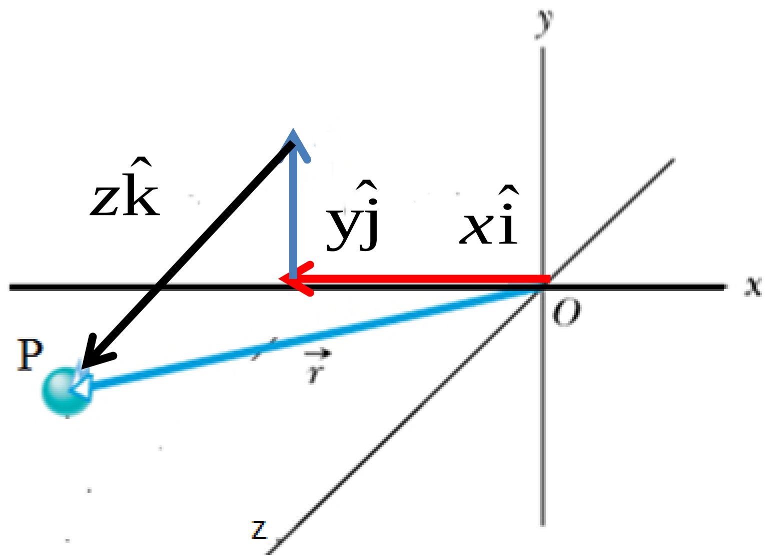
BY DR. WAJOOD DIERY

4-1 position and displacement

Position and displacement

Position

$$\boxed{\vec{r} = x\hat{\mathrm{i}} + y\hat{\mathrm{j}} + z\hat{\mathrm{k}}}$$



Displacement

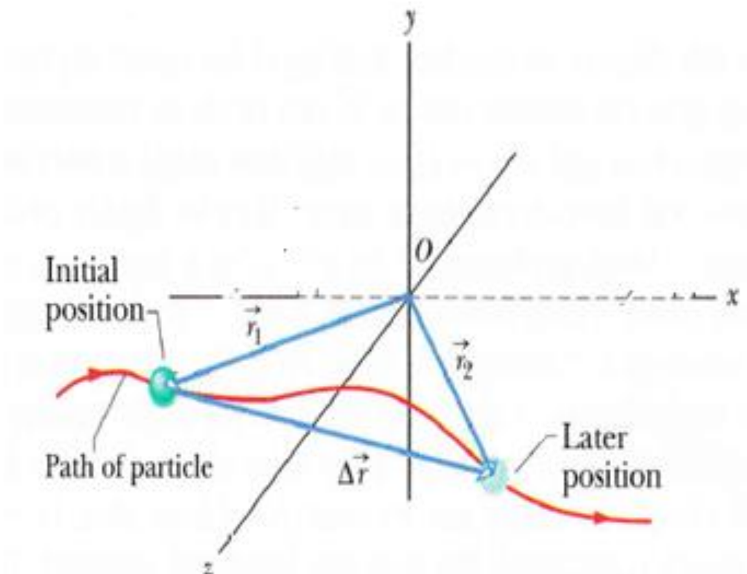
$$\boxed{\Delta\vec{r} = \vec{r}_2 - \vec{r}_1}$$

$$\vec{r}_1 = x_1\hat{\mathrm{i}} + y_1\hat{\mathrm{j}} + z_1\hat{\mathrm{k}} \text{ and } \vec{r}_2 = x_2\hat{\mathrm{i}} + y_2\hat{\mathrm{j}} + z_2\hat{\mathrm{k}}$$

$$\Delta\vec{r} = (x_2\hat{\mathrm{i}} + y_2\hat{\mathrm{j}} + z_2\hat{\mathrm{k}}) - (x_1\hat{\mathrm{i}} + y_1\hat{\mathrm{j}} + z_1\hat{\mathrm{k}})$$

$$\Delta\vec{r} = (x_2 - x_1)\hat{\mathrm{i}} + (y_2 - y_1)\hat{\mathrm{j}} + (z_2 - z_1)\hat{\mathrm{k}}$$

$$\boxed{\Delta\vec{r} = \Delta x\,\hat{\mathrm{i}} + \Delta y\,\hat{\mathrm{j}} + \Delta z\,\hat{\mathrm{k}}}$$



Problem 3 page 73

An elementary particle is subjected to a displacement of

$$\Delta\vec{r} = 2.0\,\hat{\imath} - 4.0\,\hat{\jmath} + 8.0\hat{k}$$

ending with the position vector $\vec{r} = 4.0\,\hat{\jmath} - 5.0\hat{k}$

What was the particle's initial position vector ?

Sample Problem 4.01

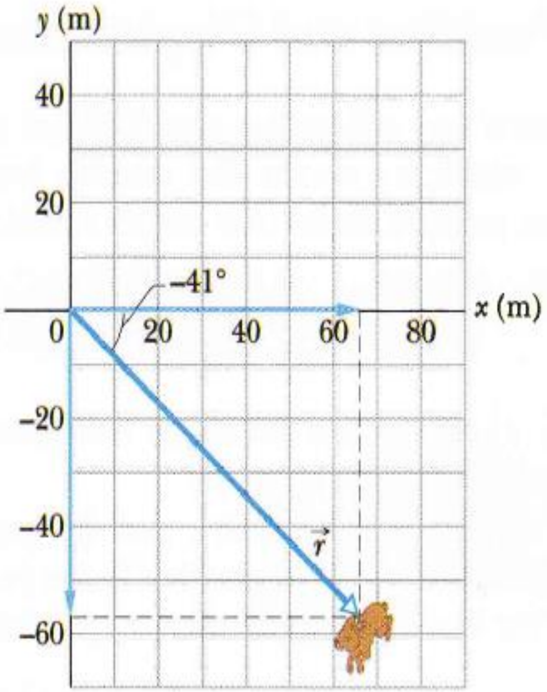
A rabbit runs across a parking lot on which a set of coordinate axes has, strangely enough, been drawn. The coordinates (meters) of the rabbit's position as functions of time t (seconds) are given by

$$x = -0.31t^2 + 7.2t + 28 \tag{4-5}$$

and

$$y = 0.22t^2 - 9.1t + 30. \tag{4-6}$$

(a) At $t = 15$ s, what is the rabbit's position vector $\vec{r}$ in unit-vector notation and in magnitude-angle notation?



4.2 Average velocity and instantaneous velocity

Average velocity

$$\vec{v}_{avg} = \frac{\Delta\vec{r}}{\Delta t}.$$

$$\vec{v}_{avg} = \frac{\Delta x\hat{i} + \Delta y\hat{j} + \Delta z\hat{k}}{\Delta t} = \frac{\Delta x}{\Delta t}\hat{i} + \frac{\Delta y}{\Delta t}\hat{j} + \frac{\Delta z}{\Delta t}\hat{k}.$$

Instantaneous velocity

$$\vec{v} = \frac{d\vec{r}}{dt}.$$

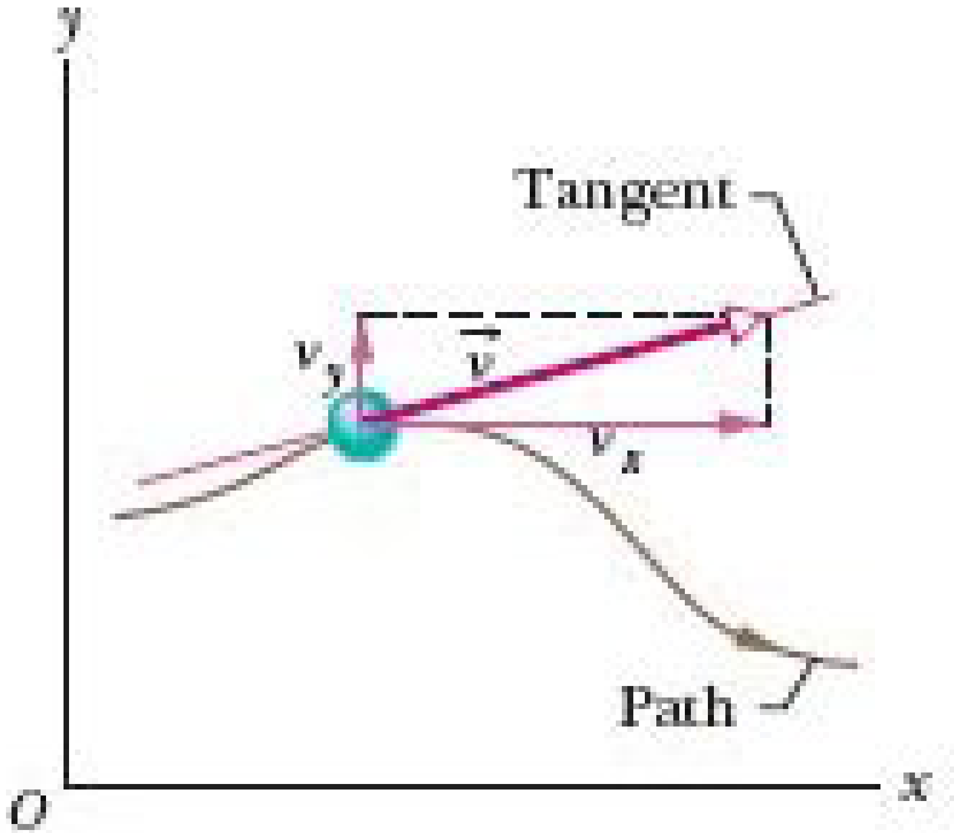
but

$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k},$$

$$\vec{v} = \frac{d}{dt}(x\hat{i} + y\hat{j} + z\hat{k}) = \frac{dx}{dt}\hat{i} + \frac{dy}{dt}\hat{j} + \frac{dz}{dt}\hat{k}$$

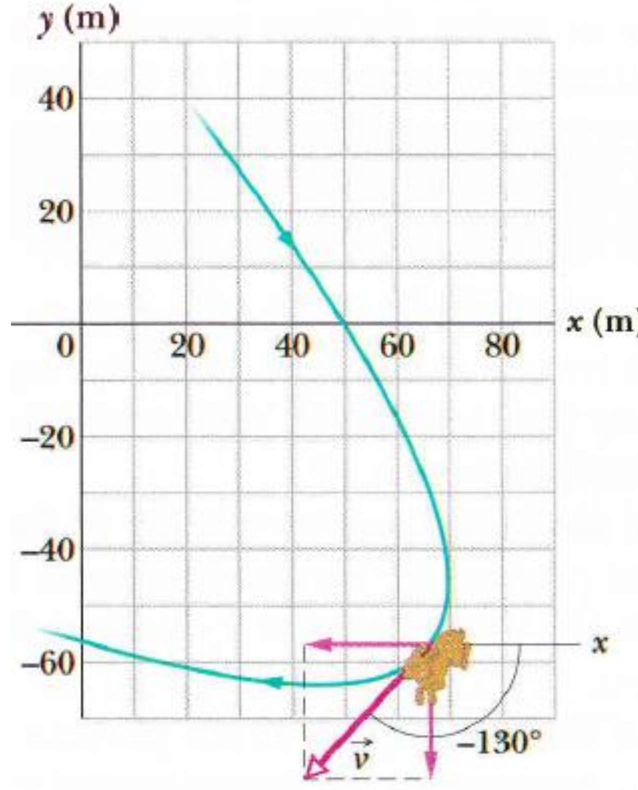
$$v_x = \frac{dx}{dt}, \quad v_y = \frac{dy}{dt}, \quad v_z = \frac{dz}{dt} \quad \Rightarrow \quad \vec{v} = v_x\hat{i} + v_y\hat{j} + v_z\hat{k}$$

The direction of the instantaneous velocity $\vec{v}$ of a particle is always tangent to the particle's path at the particle's position.



Sample Problem 4.02

For the rabbit in Sample Problem 4.01 find the velocity $\vec{v}$ at time $t = 15$ s.



4-3 Average Acceleration and Instantaneous Acceleration

Average Acceleration

$$\boxed{\vec{a}_{avg} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t} = \frac{\Delta \vec{v}}{\Delta t}}$$

Instantaneous Acceleration

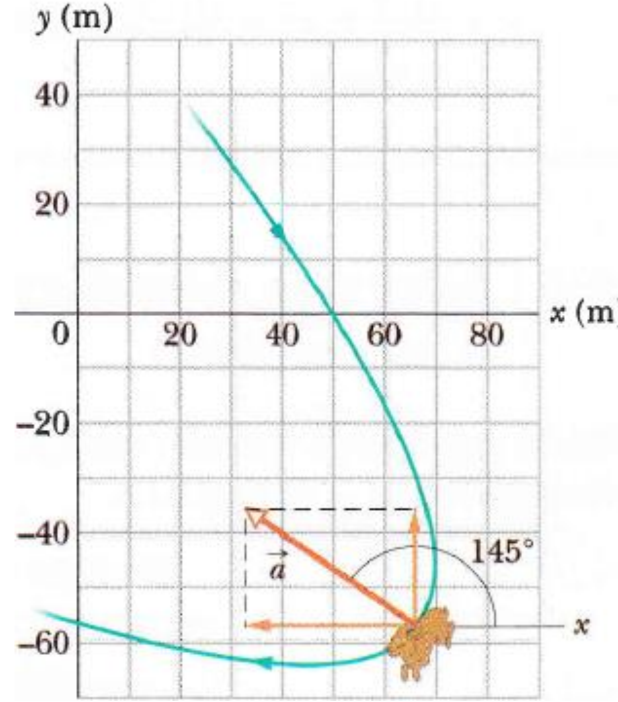
$$\boxed{\vec{a} = \frac{d\vec{v}}{dt}}$$ but $$\boxed{\vec{v} = v_x\hat{\mathrm{i}} + v_y\hat{\mathrm{j}} + v_z\hat{\mathrm{k}}}$$

$$\vec{a} = \frac{d}{dt}(v_x\hat{\mathrm{i}} + v_y\hat{\mathrm{j}} + v_z\hat{\mathrm{k}}) = \frac{dv_x}{dt}\hat{\mathrm{i}} + \frac{dv_y}{dt}\hat{\mathrm{j}} + \frac{dv_z}{dt}\hat{\mathrm{k}}$$

$$\boxed{a_x = \frac{dv_x}{dt}} \quad \boxed{a_y = \frac{dv_y}{dt}} \quad \boxed{a_z = \frac{dv_z}{dt}} \Rightarrow \boxed{\vec{a} = a_x\hat{\mathrm{i}} + a_y\hat{\mathrm{j}} + a_z\hat{\mathrm{k}}}$$

Sample Problem 4.03

For the rabbit in Sample Problems 4.01 and 4.02 find the acceleration $\vec{a}$ at time $t = 15$ s.



Problem 15 page 74

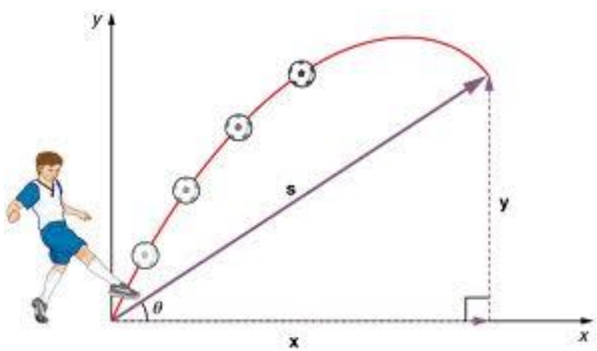
From the origin, a particle starts at t=0 s with a velocity $\vec{v} = 7.0\,\hat{\imath}\ m/s$ and moves in the xy plane with a constant acceleration of $\vec{a} = -9.0\,\hat{\imath} + 3.0\,\hat{\jmath}$ (m/s^2). At the time particle reaches the maximum x coordinate, what is it's (a) velocity and (b) position vector?

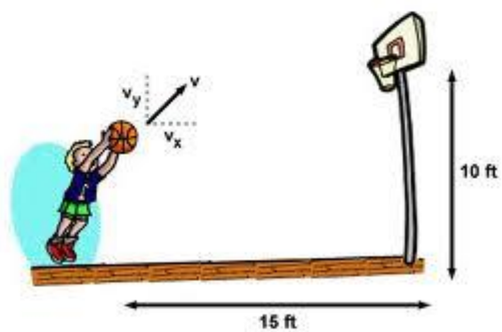
Sample Problem 4-5

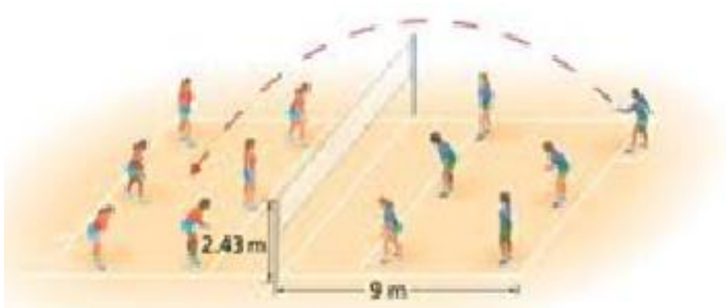
A particle with velocity $\vec{v}_0 = -2.0\hat{\text{i}} + 4.0\hat{\text{j}}$ (in meters per second) at $t = 0$ undergoes a constant acceleration $\vec{a}$ of magnitude $a = 3.0 \text{ m/s}^2$ at an angle $\theta = 130°$ from the positive direction of the x axis. What is the particle's velocity $\vec{v}$ at $t = 5.0$ s?

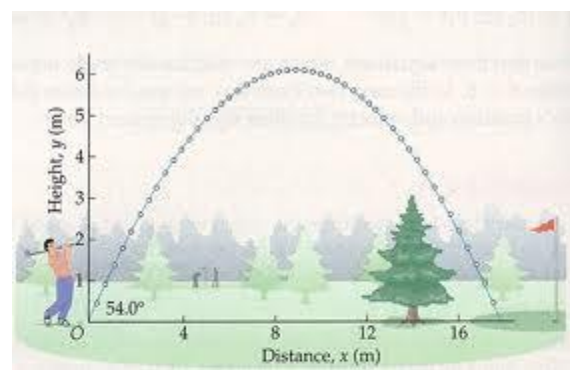
4.4 Projectile Motion

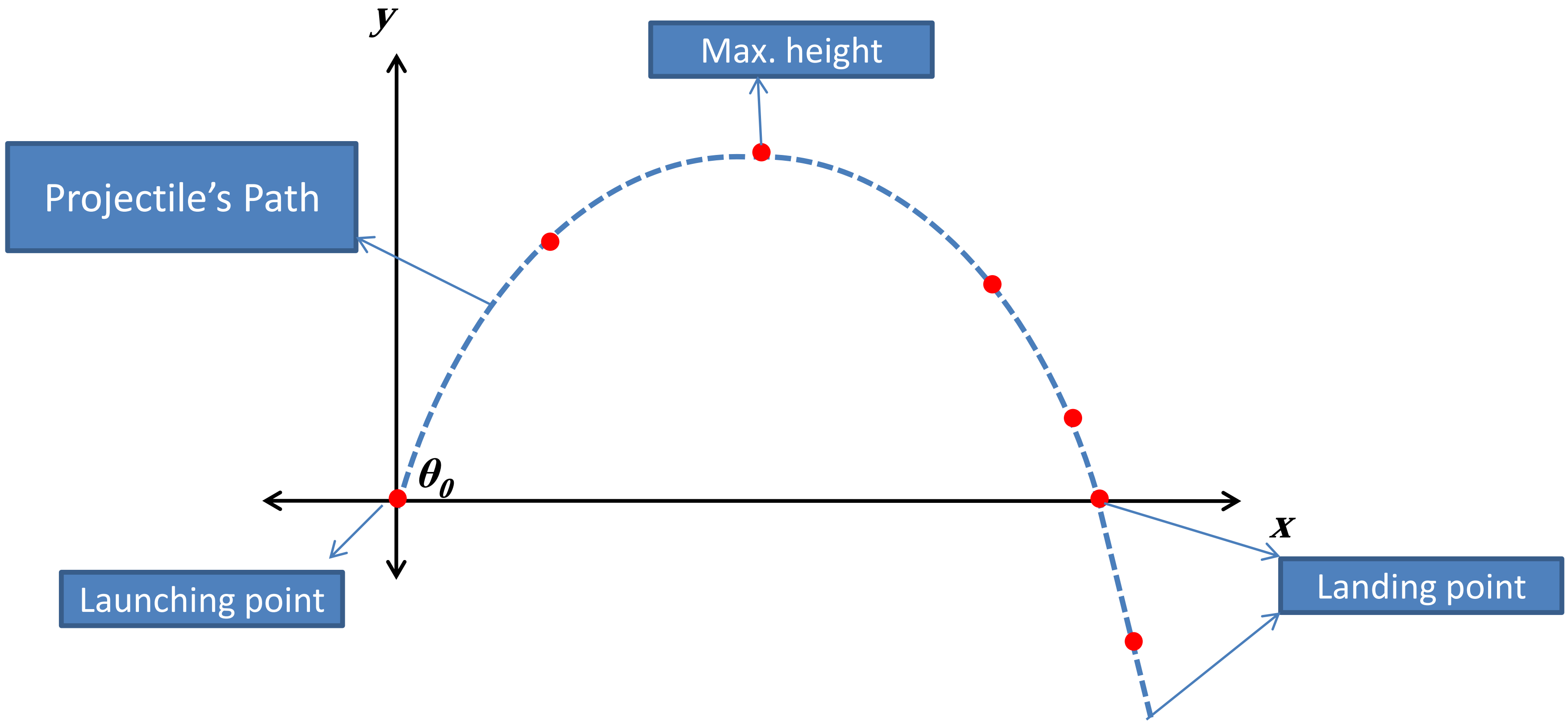
is the motion of a particle that is launched with an initial Velocity $\vec{v}_0$ and its acceleration is always the free fall Acceleration -g.





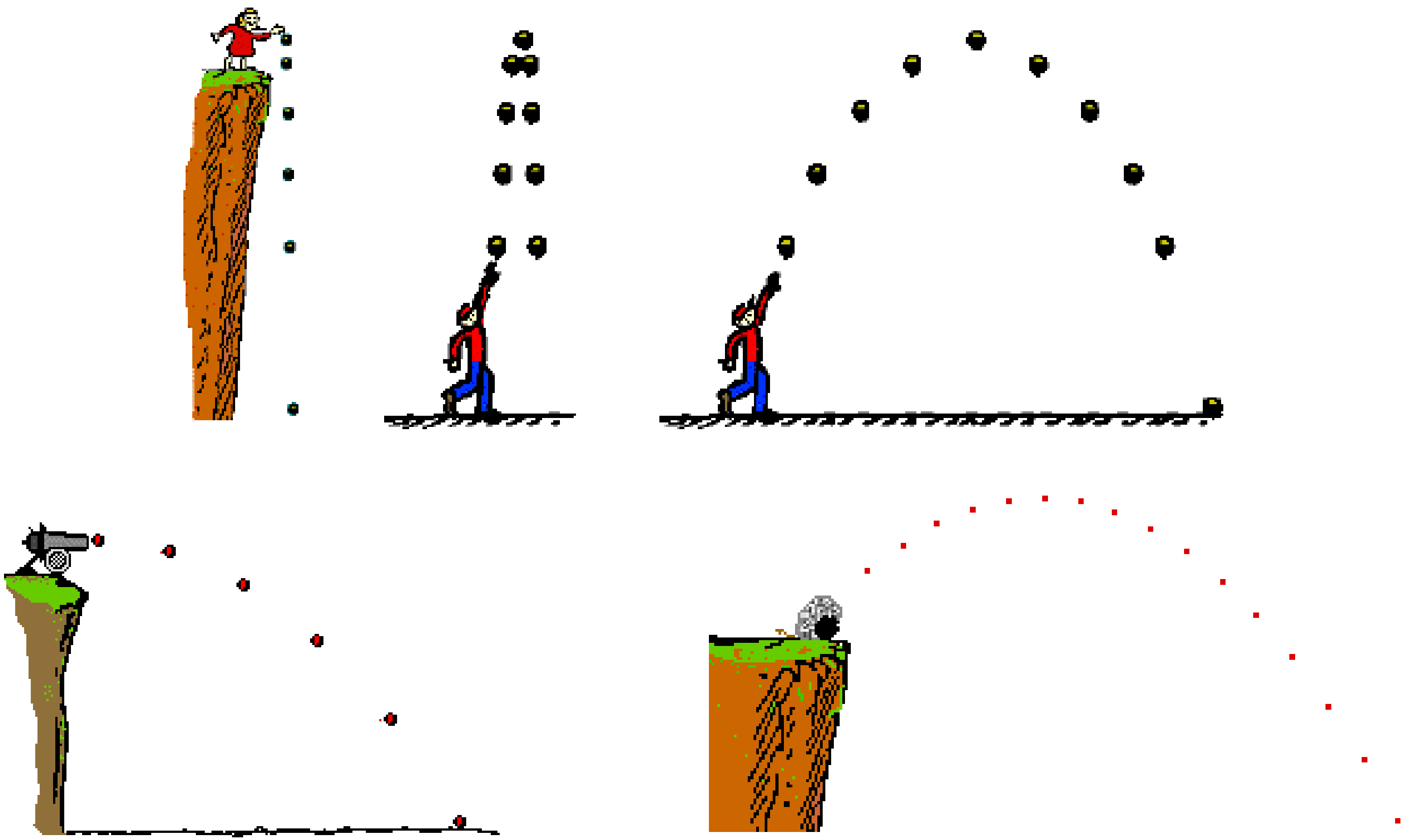


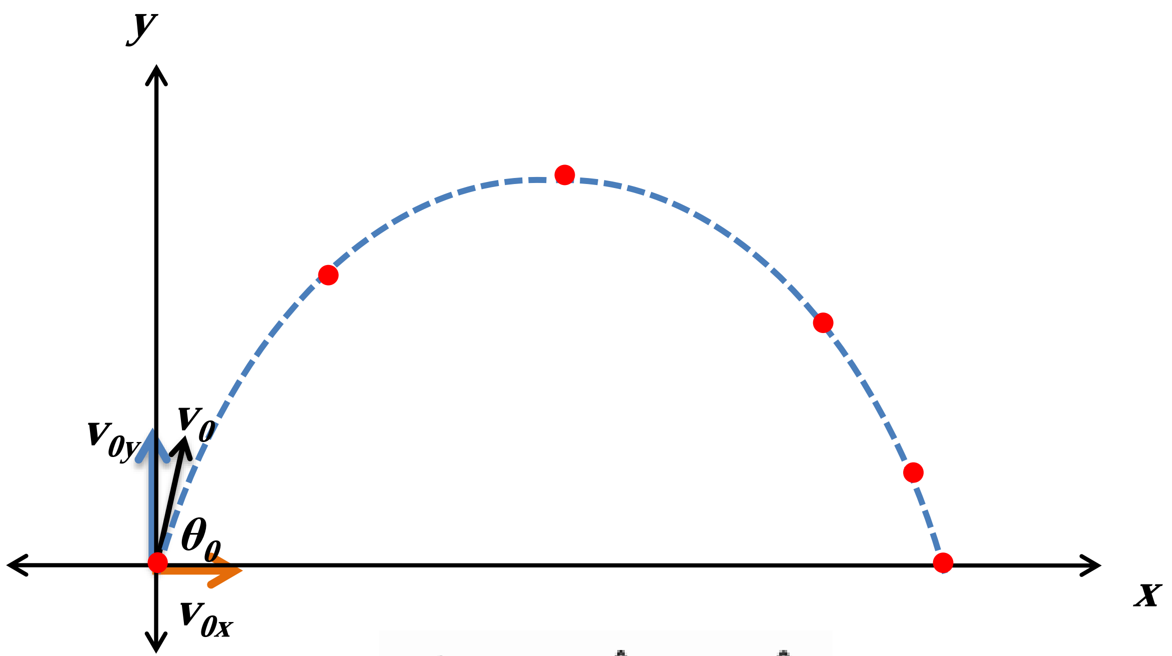




Max. height
Projectile's Path
y
θ_0
x
Launching point
Landing point

Types of Projectiles





$$\vec{v}_0 = v_{0x}\hat{\mathrm{i}} + v_{0y}\hat{\mathrm{j}}.$$

$$v_{0x} = v_0 \cos\theta_0 \qquad v_{0y} = v_0 \sin\theta_0$$

In projectile motion, the horizontal motion and the vertical motion are independent of each other; that is, neither motion affects the other.

Projectile motion

Horizontal Motion

No Force

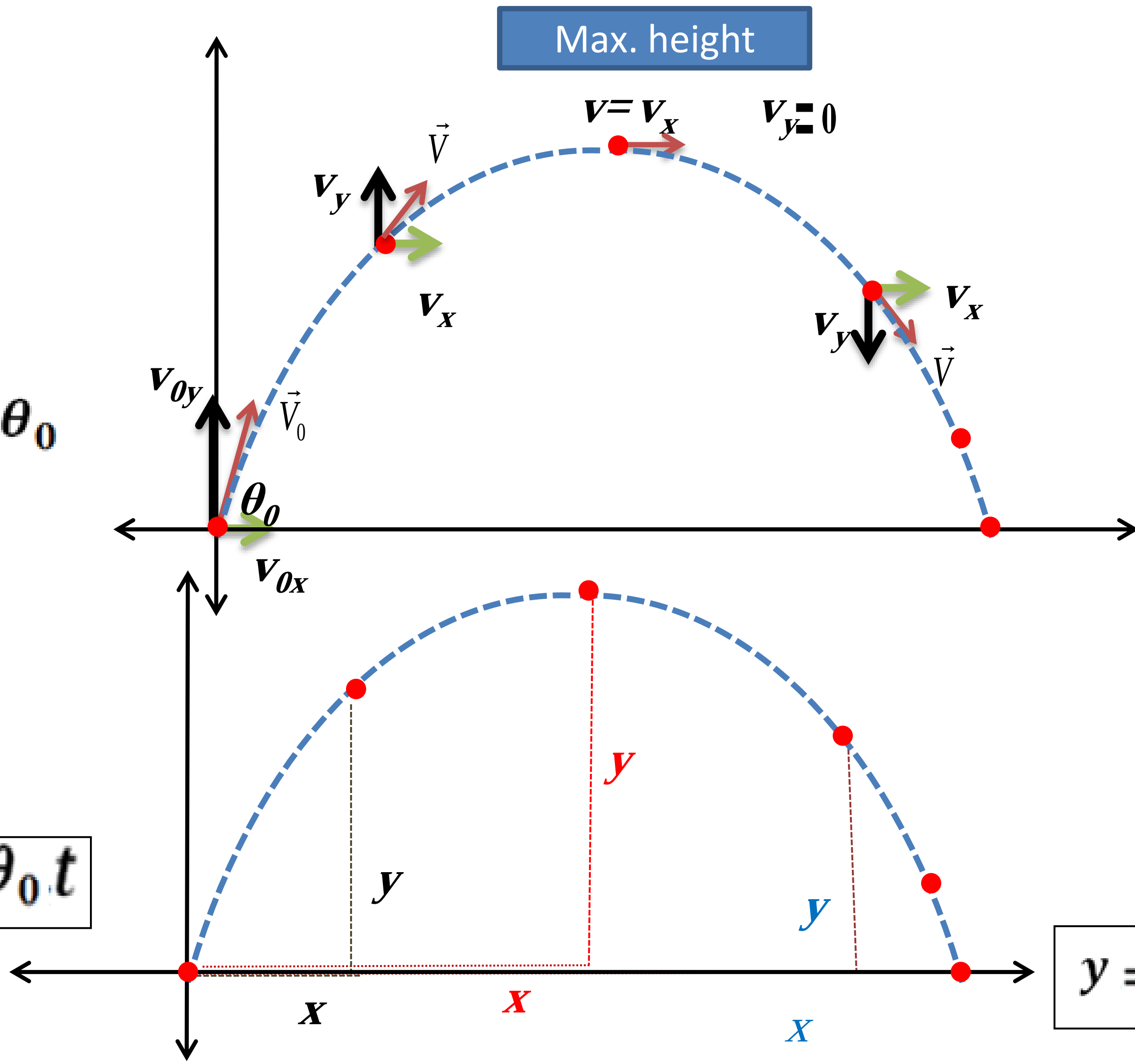
$$\boxed{a_x = 0}$$

$$v_{0x}=v_0\cos\theta_0$$

$$\boxed{v_x = v_{0x}}$$

$$x = v_{0x}t$$

$$\boxed{x = v_0\cos\theta_0\, t}$$



Vertical Motion

Gravity

$$\boxed{a_y = -g}$$

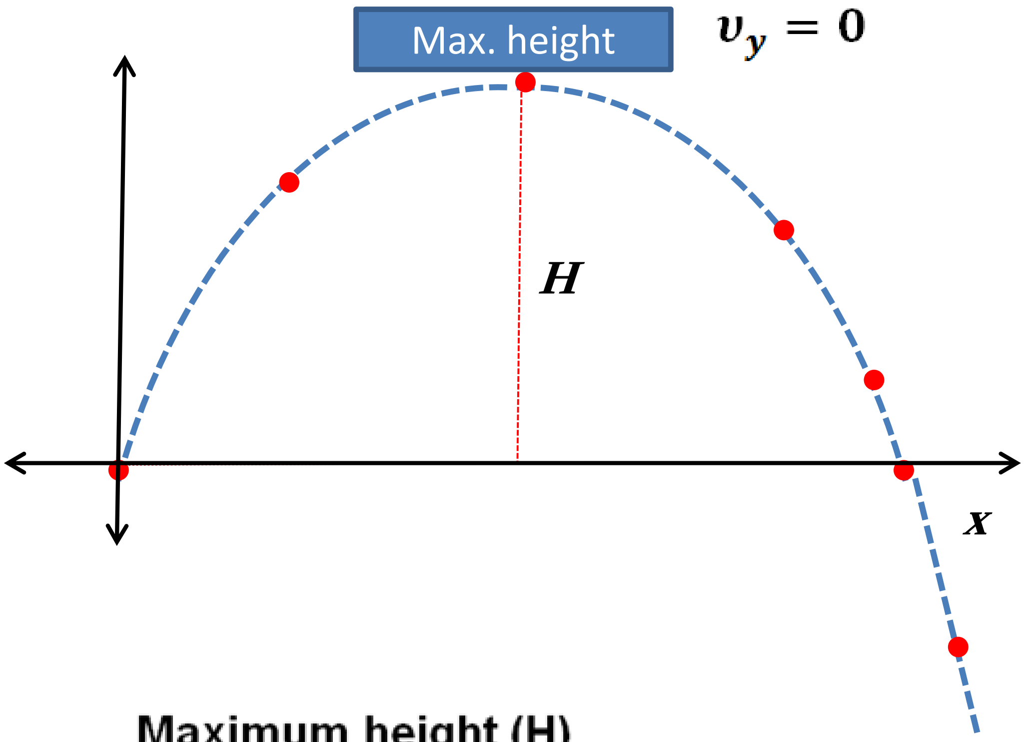
$$\boxed{v_{0y}=v_0 \sin\theta_0}$$

$$v_y = v_{0y} - g\,t$$

$$\boxed{v_y=v_0 \sin\theta_0 - g\,t}$$

$$y = v_{0y}t - \tfrac{1}{2}gt^2$$

$$\boxed{y=v_0 \sin\theta_0\; t - \tfrac{1}{2}gt^2}$$



Maximum height (H)

$$\boxed{H = \frac{(v_0 \sin\theta_0)^2}{2g}}$$

Problem 22 page 74 :

A small ball rolls horizontally off the edge of a tabletop that is 1.50 m high. It strikes the floor at a point 1.52 m horizontally from the table edge. (a) How long is the ball in the air? (b)What is its speed at the instant it leaves the table?

Problem 32 page 75:

You throw a ball toward a wall at speed 25.0 m/s and at angle θ_0 =40.0° above the horizontal (fig 4-26). The wall is distance d =22.0 m from the release point of the ball.

(a)How far above the release point does the ball hit the wall? What are the (b) horizontal and (c) vertical components of its velocity as it hits the wall?

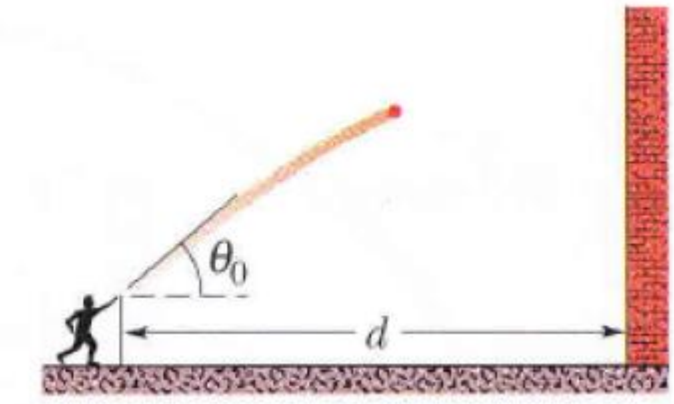


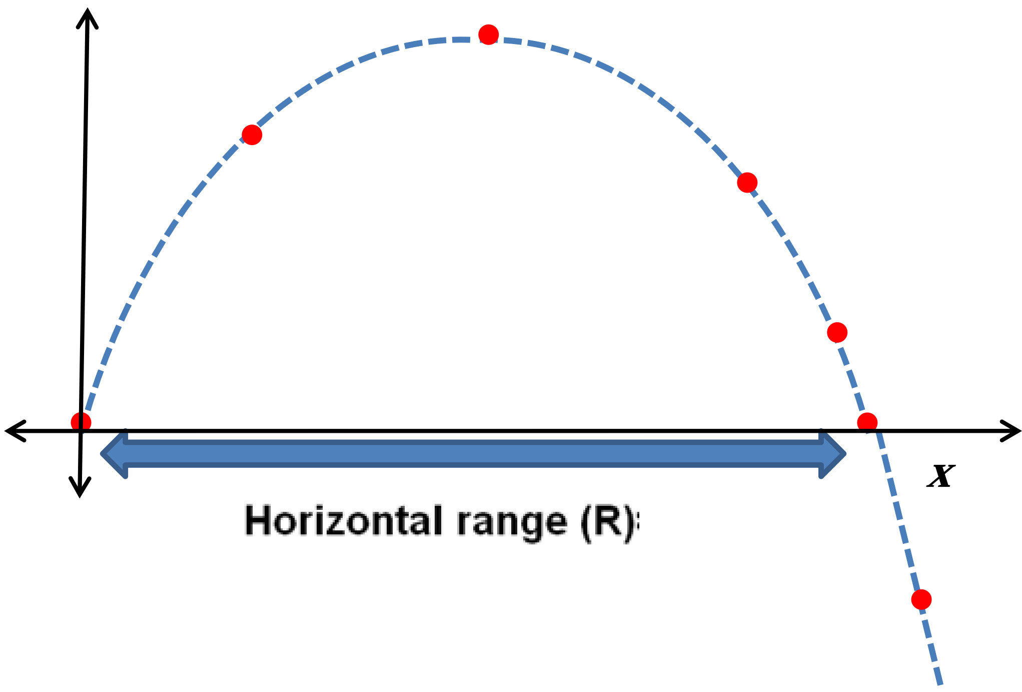
Figure 4-26

d)When it hits, has it passed the highest point on its trajectory?

The Horizontal Range

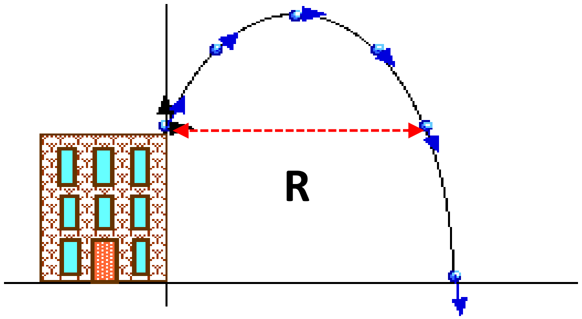
horizontal range R, which is the horizontal distance from the launch point to the point at which the particle returns to the launch height, is

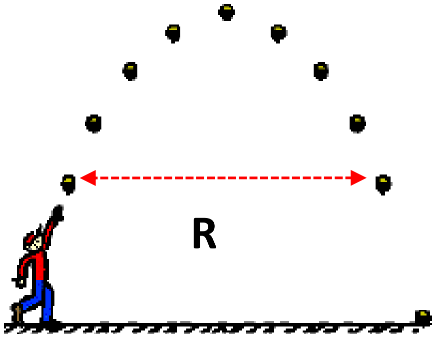
$$R = \frac{v_0^2}{g}\sin 2\theta_0$$



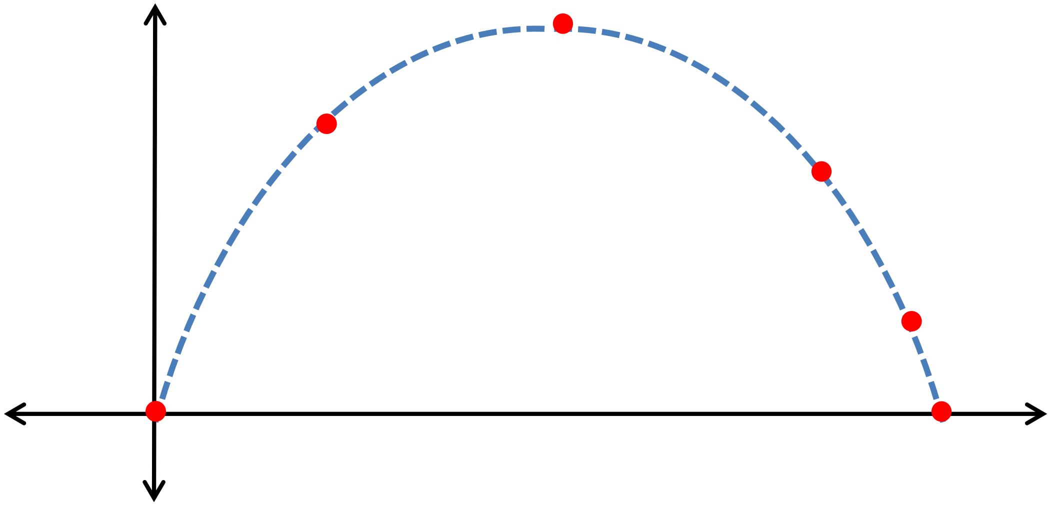
Maximum range

$$\theta_0 = 45^0 \rightarrow R_{max} = \frac{v_0^2}{g}$$





The Equation of the Projectile Path (TRAJECTORY)



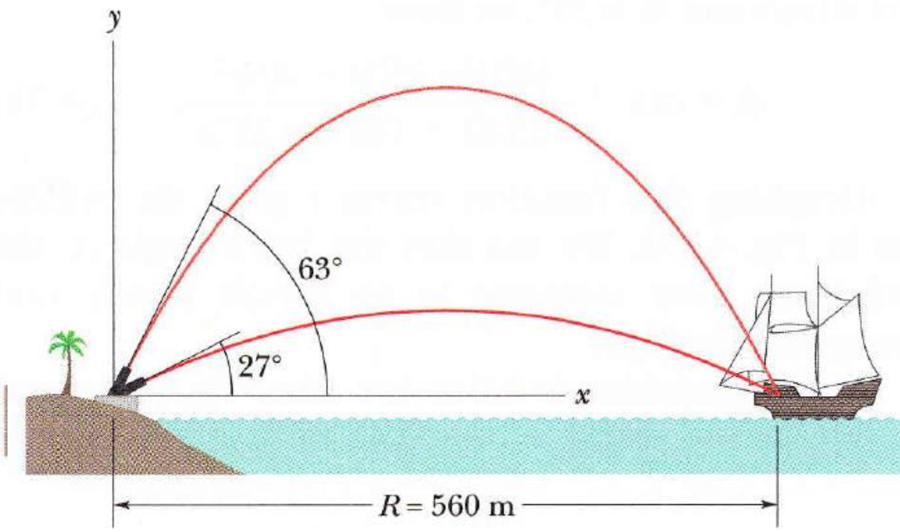
$$y = (\tan \theta_0)x - \frac{gx^2}{2(v_0 \cos \theta_0)^2}$$

This is the equation of a parabola, so the projectile path is parabolic

EXTERNAL EXAMPLE

Figure 4-16 shows a pirate ship 560 m from a fort defending a harbor entrance. A defense cannon, located at sea level, fires balls at initial speed $v_0 = 82$ m/s.

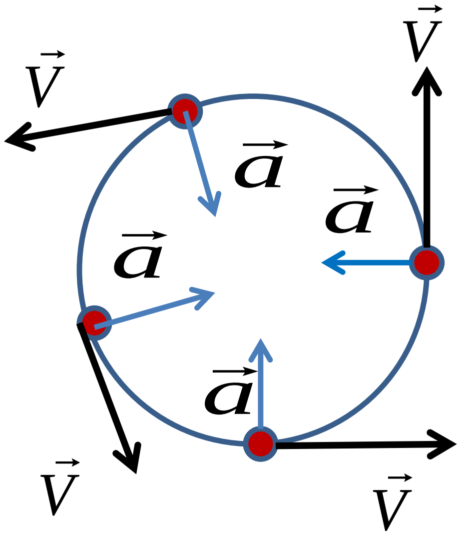
(a) At what angle θ_0 from the horizontal must a ball be fired to hit the ship?



(b) What is the maximum range of the cannonballs?

4-5 Uniform Circular Motion

A particle is in uniform circular motion if it travels around a circle or circular arc at **constant speed.**



1-Velocity :

-magnitude constant v.

-direction :tangent to the circle in the direction of motion.

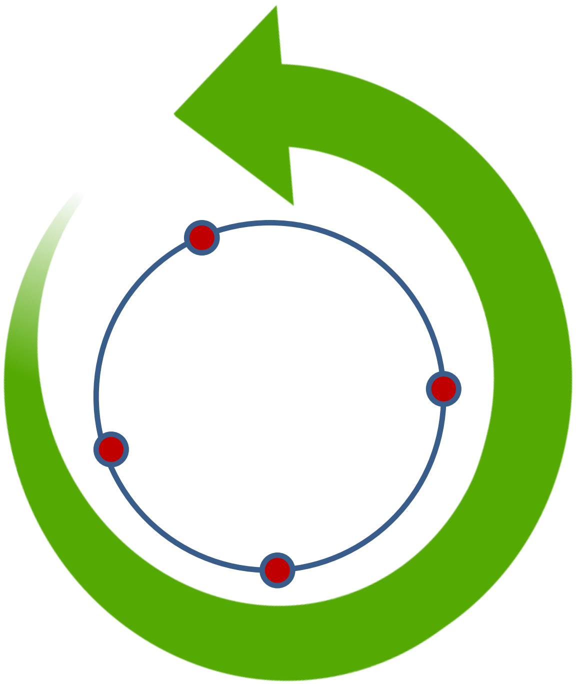
2- Acceleration:

Why is the particle accelerating even though the speed does not vary?

- magnitude $a = \dfrac{v^2}{r}$

- direction: toward the center.

- It is called **Centripetal(meaning seeking center) acceleration**



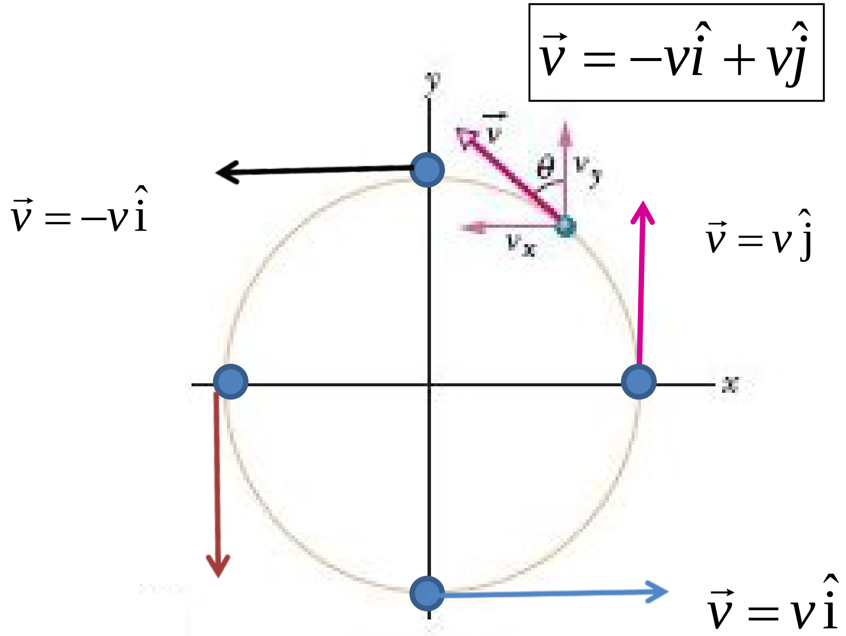
3- Period: is the time for a particle go around the circle once.

$$\text{Time} = \frac{\text{distance}}{\text{velocity}}$$

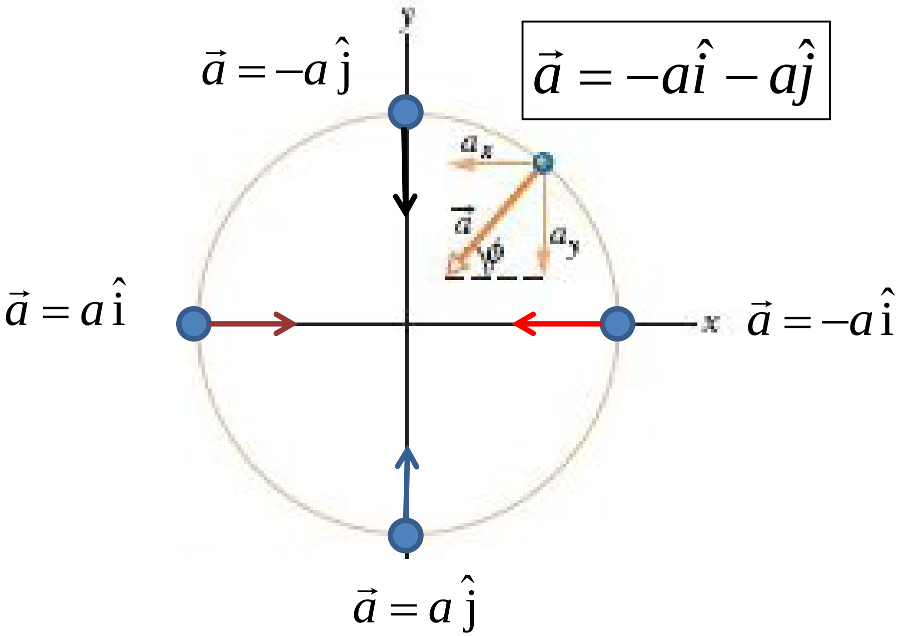
For one round $\Rightarrow$ distance = circumference of the circle

$$\boxed{T = \frac{2\pi r}{v}}$$

$$\boxed{\vec{v} = v_x\hat{i} + v_y\hat{j}}$$

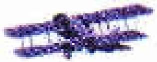


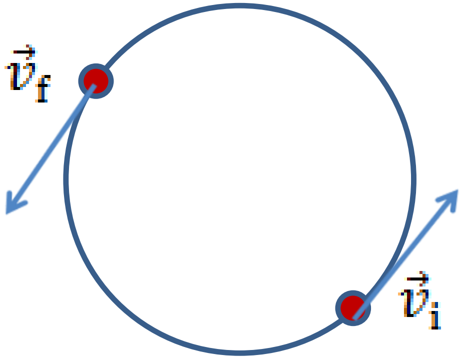
$$\boxed{\vec{a} = a_x\hat{i} + a_y\hat{j}}$$



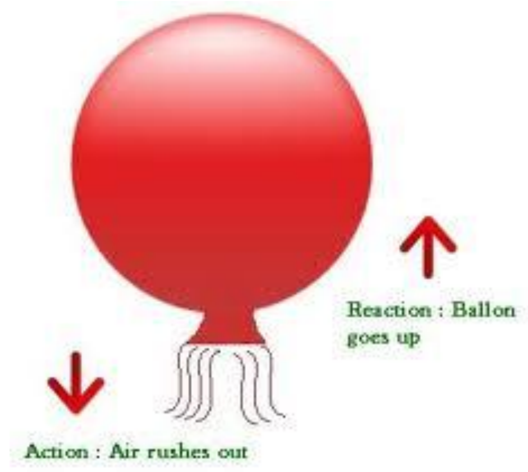
Sample Problem 4.06

What is the magnitude of the acceleration, in g units, of a pilot whose aircraft enters a horizontal circular turn with a velocity of $\vec{v}_i = (400\hat{i} + 500\hat{j})$ m/s and 24.0 s later leaves the turn with a velocity of $\vec{v}_f = (-400\hat{i} - 500\hat{j})$ m/s?

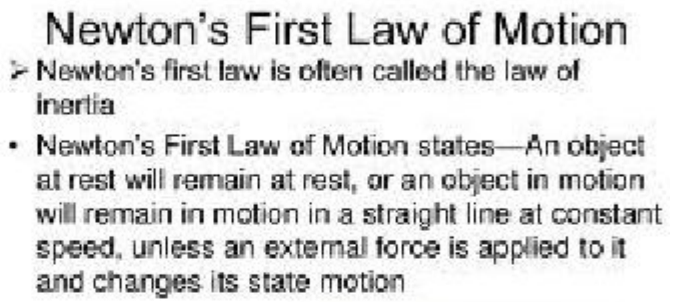


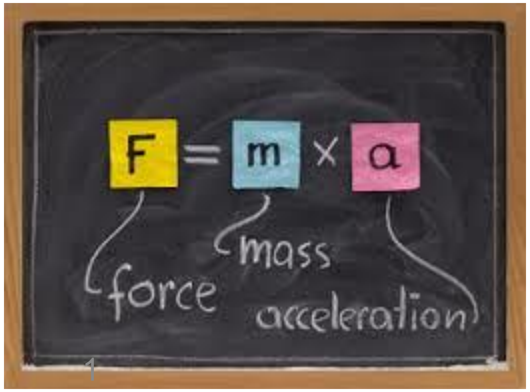



The End



Force and Motion I





By: Dr. Wajood Diery

5-1 Newton's First and Second Law

What is Physics?

To study the motion of an object

↓

We usually study the acceleration of this object

↓

Acceleration is the changing in velocity

↓

The cause of this changing is a **Force**

Newton's First Law

If No Force acts on a body, the body's velocity cannot change; that is, the body cannot Accelerate.

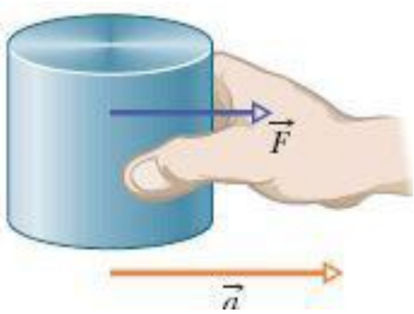
or

If there is **No Force** that acts on the body

if the body is at rest , it stays at rest

if the body is in motion, it stays in motion with the same velocity (same speed and direction)

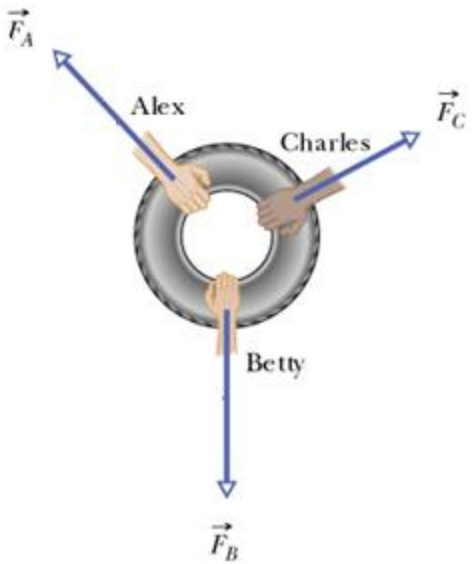
Force



Thus, a force is measured by the acceleration it produces.

- Its Unit is Newton N .
- It is a Vector. $\vec{F}$

If several forces act on a body



$$\vec{F}_{\text{net}} = \vec{F}_A + \vec{F}_B + \vec{F}_C$$

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

Mass

- Mass is an ***intrinsic*** characteristic of a body that relates a ***force F*** applied on the body and the resulting ***acceleration a*.**

- **SI Unit is Kg.**

- **It is a scalar.**

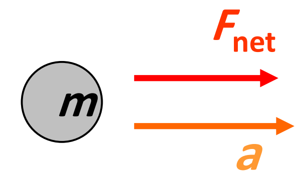
$$\frac{m_X}{m_0} = \frac{a_0}{a_X} \rightarrow \boxed{m_X = m_0 \frac{a_0}{a_X}}$$

Newton's second Law

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

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

$$F_{\text{net},x} = ma_x \qquad F_{\text{net},y} = ma_y \qquad F_{\text{net},z} = ma_z$$



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.

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

$$\textit{If}\ \vec{F}_{net} = 0 \Rightarrow a = 0 \Rightarrow v \text{ is constant.}$$

$$\Leftarrow \qquad \Leftarrow$$

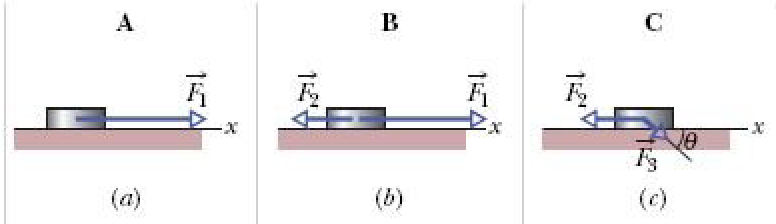
At rest, constant velocity, equilibrium $\Rightarrow \quad F_{net} = 0$

Free body diagram

1. Draw x and y coordinates.
2. The body is represented by a dot at the origin.
3. Each Force on the body is drawn as a vector arrow with its tail on the body.

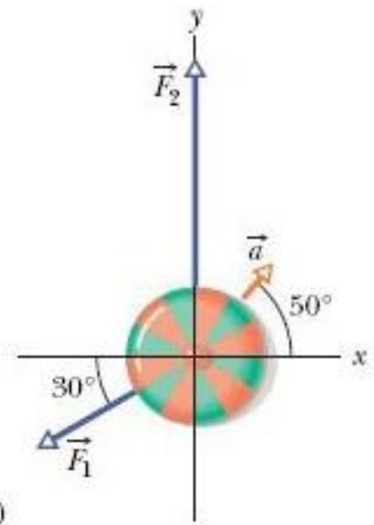
Sample Problem (5.01)

Figures 5-3*a* to *c* show three situations in which one or two forces act on a puck that moves over frictionless ice along an x axis, in one-dimensional motion. The puck's mass is $m = 0.20$ kg. Forces $\vec{F}_1$ and $\vec{F}_2$ are directed along the axis and have magnitudes $F_1 = 4.0$ N and $F_2 = 2.0$ N. Force $\vec{F}_3$ is directed at angle $\theta = 30°$ and has magnitude $F_3 = 1.0$ N. In each situation, what is the acceleration of the puck?



Sample Problem (5.02)

In the overhead view of Fig. 5-4*a*, a 2.0 kg cookie tin is accelerated at 3.0 m/s^2 in the direction shown by $\vec{a}$, over a frictionless horizontal surface. The acceleration is caused by three horizontal forces, only two of which are shown: $\vec{F}_1$ of magnitude 10 N and $\vec{F}_2$ of magnitude 20 N. What is the third force $\vec{F}_3$ in unit-vector notation and in magnitude-angle notation?



(*a*)

5-2 Some particular forces

Gravitational force

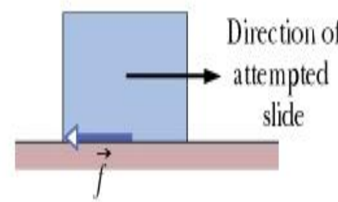
It is the force that the Earth exerts on any object. It is directed toward the center of the Earth.

Normal force

When a body presses against a surface, the surface deforms and pushes on the body with a normal force perpendicular to the contact surface.

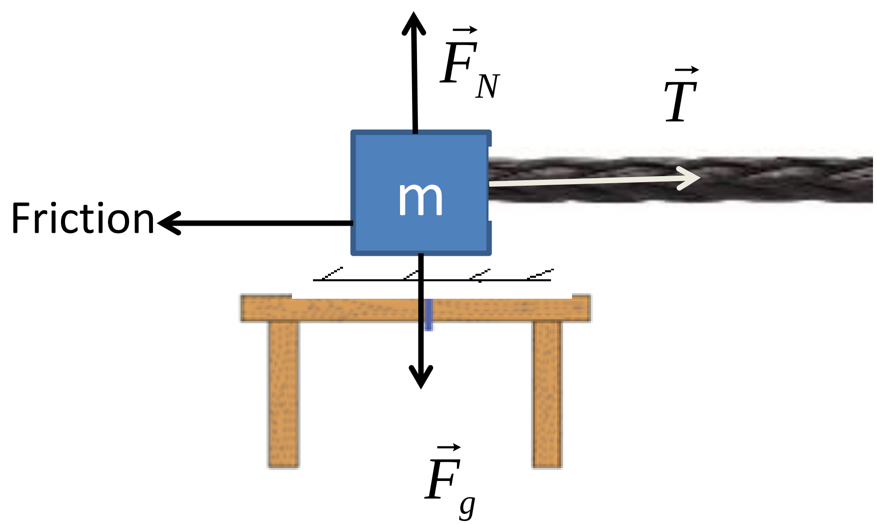
Friction

The force that opposes the motion.



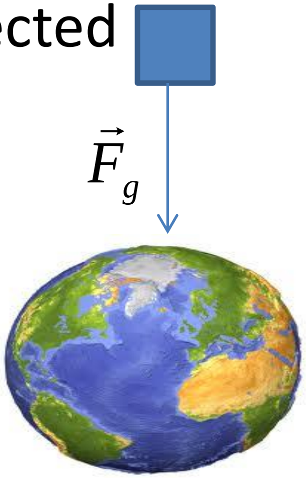
Tension

This is the force exerted by a rope or a cable attached to an object.



Gravitational force

- It is the force that the Earth exerts on any object .It is directed toward the center of the Earth.



$$F_{\text{net},y} = ma_y \qquad -F_g = m(-g) \qquad \boxed{F_g = mg}$$

$$\vec{F}_g = -F_g\hat{\text{j}} = -mg\hat{\text{j}} = m\vec{g}$$

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

$$\boxed{w = \left|\vec{F}_g\right| = mg}$$

mass

- mass is constant.
- Unit: kg.

weight

- weight is changeable, It depends on g.
- Unit: N.

Normal force

The body at rest or moving with constant velocity.

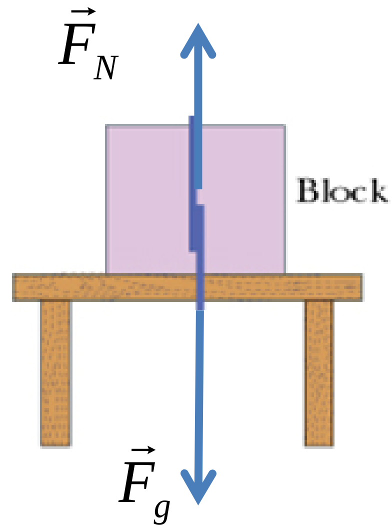
$$a = 0$$

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

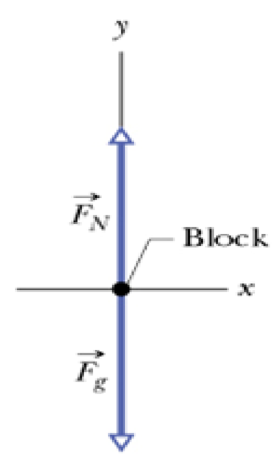
$$F_{net,y} = ma_y$$

$$F_N - F_g = 0$$

$$\boxed{F_N = F_g = mg}$$



Direction of motion



Direction of motion

The body is moving with acceleration

$$a = a_y$$

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

$$F_{net,y} = ma_y$$

$$F_N - F_g = ma_y$$

$$F_N = F_g + ma_y$$

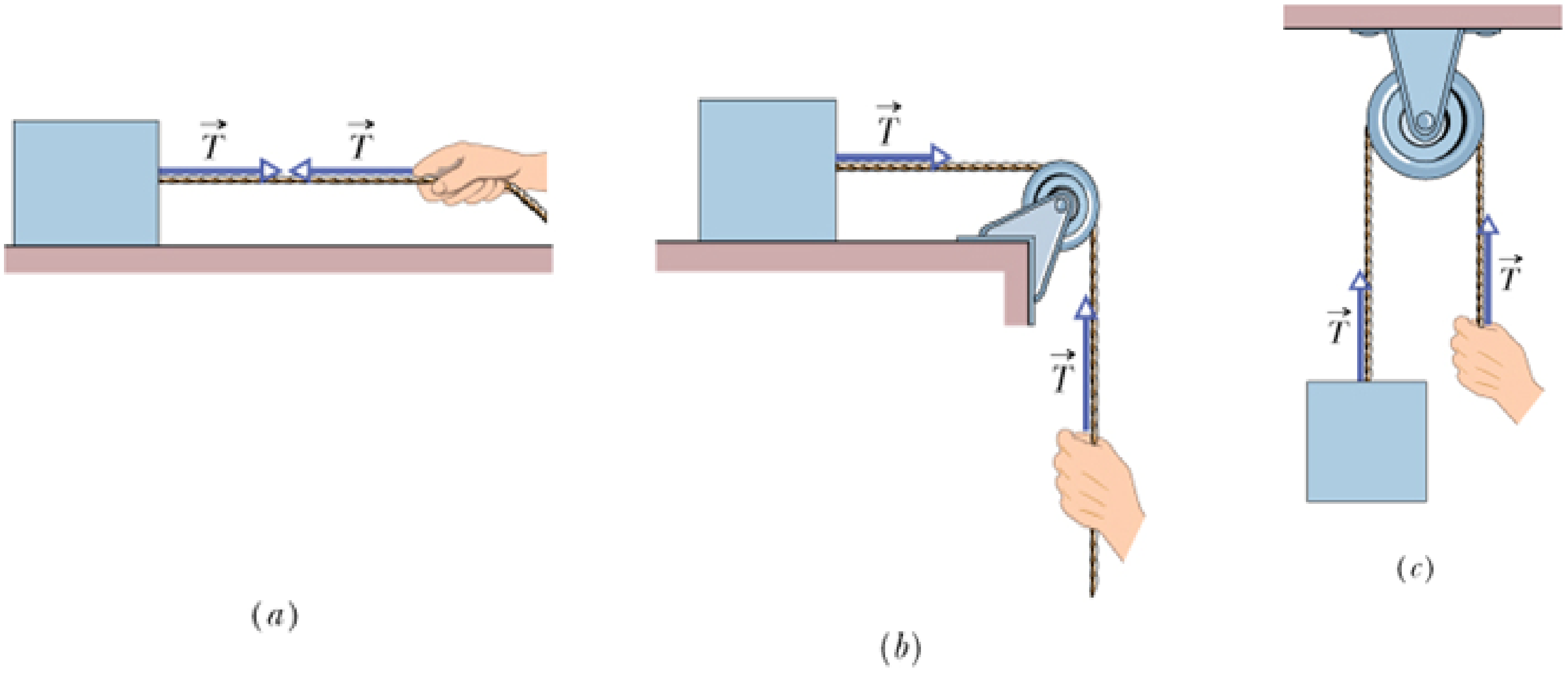
$$= mg + ma_y$$

$$\boxed{F_N = (g + a_y)m}$$

Tension

Tension has the following characteristics:

1. It is always directed along the rope.
2. It is always pulling the object.
3. It has the same value along the rope.



5-3 Applying Newton's Laws

Newton's Third Law

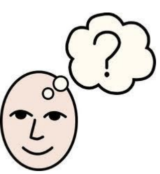
When two bodies interact by exerting forces on each other, the forces are equal in magnitude and opposite in direction.

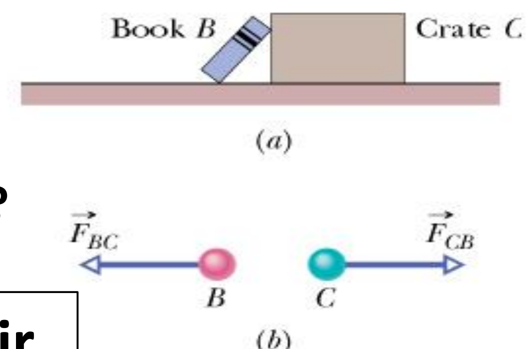
There is a horizontal force on the book from the crate denoted by $\vec{F}_{BC}$

and a horizontal force on the crate from the book denoted by $\vec{F}_{CB}$

$$F_{BC} = F_{CB} \quad \text{(equal magnitude)}$$

$$\vec{F}_{BC} = -\vec{F}_{CB} \quad \text{(equal magnitude and opposite direction)}$$



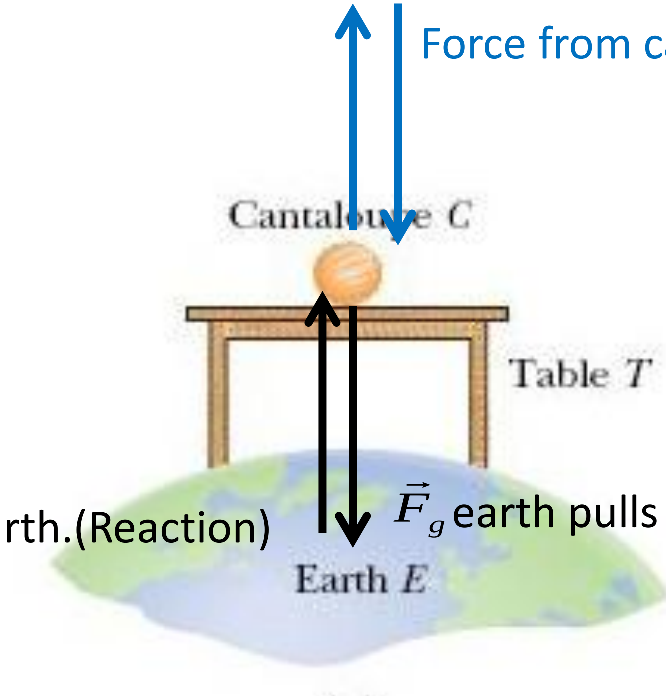


Why the action and reaction force do not cancel each other?

Action and reaction are called third-law force pair

F_n :force from table on the Cantaloupe(action)

Force from cantaloupe on the table (reaction)

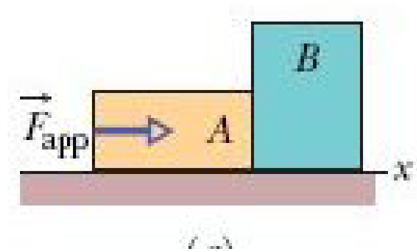


Cantaloupe pulls on the earth.(Reaction)

$\vec{F}_g$ earth pulls on Cantaloupe .(Action)

Sample Problem (5.07): Acceleration of Block pushing on Block

In Fig. 5-20*a*, a constant horizontal force $\vec{F}_{app}$ of magnitude 20 N is applied to block *A* of mass $m_A = 4.0$ kg, which pushes against block *B* of mass $m_B = 6.0$ kg. The blocks slide over a frictionless surface, along an *x* axis.



(a) What is the acceleration of the blocks?

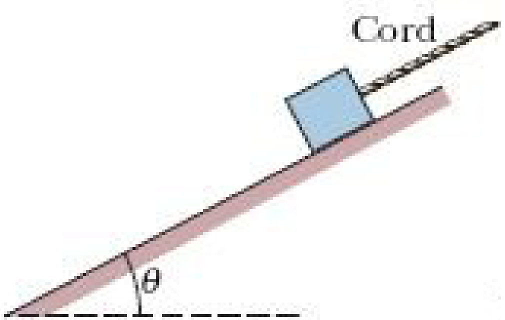
(b) What is the (horizontal) force $\vec{F}_{BA}$ on block *B* from block *A* (Fig. 5-20*c*)?

Recipe for the Application of Newton's Laws of Motion for a single particle

1. Identify all the forces that act on the particle. Label them on the diagram and the direction of motion of the object if it is moving.
2. Draw a free-body diagram for the object.
3. Check if there is any force needs to be resolved.
4. Write Newton 2ed law.
5. decide how many equations do you need, if its one-dimension, need one equation, two-dimension ,you need two equations.
6. If the object at rest or moving with constant velocity, then the acceleration is zero (a=0) along that axis, otherwise it a has a value.
7. Add the forces along each axis Geometrically(i.e along x-axis: to the right (+), to the left (-). Along y-axis :upward (+), downward (-).
8. solve the equation to find the unknown.

Sample Problem 5.04: Cord accelerates box up a ramp

In Fig. 5-16*a*, a cord pulls on a box of sea biscuits up along a frictionless plane inclined at $\theta = 30°$. 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?



Sample Problem (5.06): Forces within an elevator cab

In Fig. 5-19*a*, a passenger of mass $m = 72.2$ kg stands on a platform scale in an elevator cab. We are concerned with the scale readings when the cab is stationary and when it is moving up or down.

(a) Find a general solution for the scale reading, whatever the vertical motion of the cab.

(b) What does the scale read if the cab is stationary or moving upward at a constant 0.50 m/s?

(c) What does the scale read if the cab accelerates upward at 3.20 m/s^2 and downward at 3.20 m/s^2?

Recipe for the Application of Newton's Laws of Motion for a system of particles

1. Identify all the forces that act on the system. Label them on the diagram and the direction of motion of each object if they are moving.

2. Remember that the system of two objects moves with the **same acceleration.**

3. Choose one object to start with and follow the steps below:

a) Draw a free-body diagram for the object.

b) Check if there is any force need to be resolved.

c) Write Newton 2ed law.

d) decide how many equations do you need, if its one-dimension, need one equation, two-dimension ,you need two equations.

e) If the object at rest or moving with constant velocity, then (a=0) the acceleration is zero along that axis, otherwise a has a value.

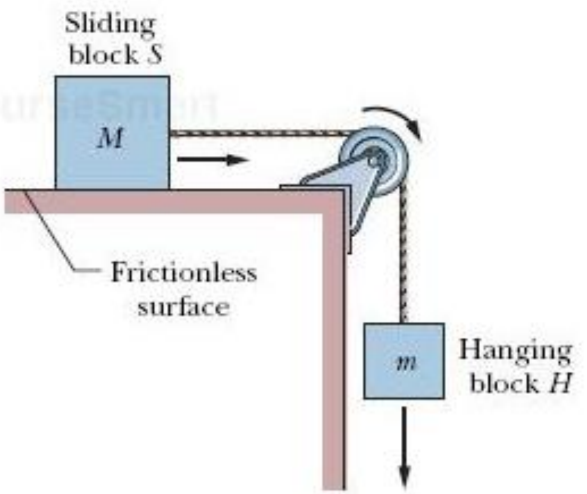
f) simplify the equation you get and label it (1)

4.Now Apply step(3) to the other object till you get another equation and label (2).

5. Solve the two Equations to find the unknown.

Sample Problem 5.03: Block on table, block hanging

Figure 5-13 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.

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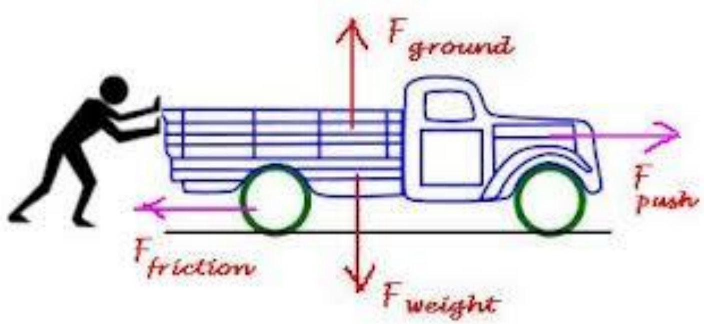
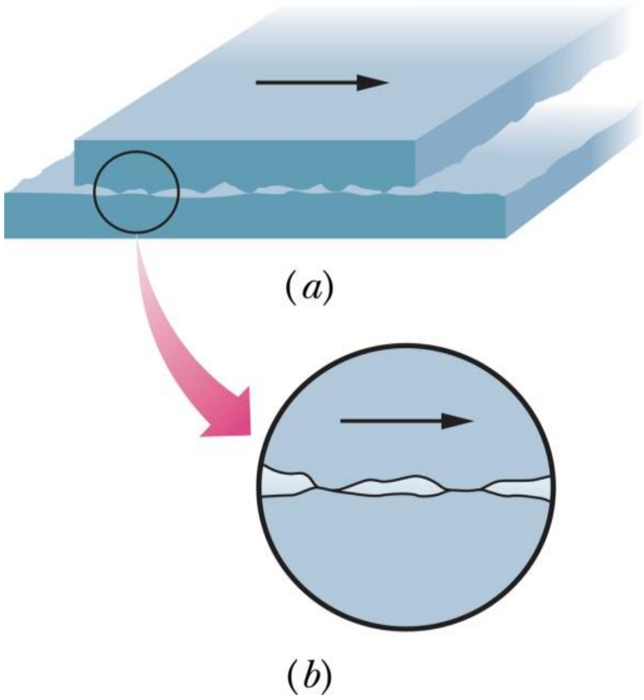


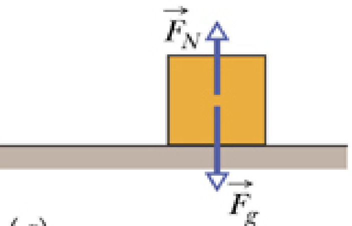
Chapter 6
Force and Motion II

By: Dr. Wajood Diery

6-2 | Friction

- Definition.
- Is it Bad or good?
- Cause of friction.

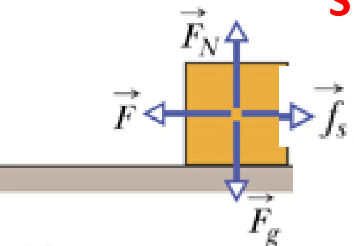




(a)

No fractional force

Static fractional force



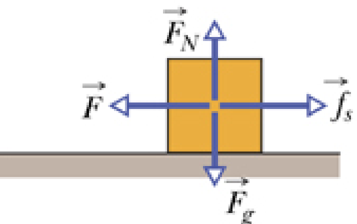
(b)

The body does not move

$$F_{net,x} = 0$$

$$f_s - F = 0$$

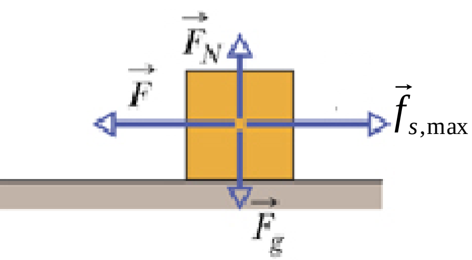
$$F = f_s$$



(c)

The body does not move

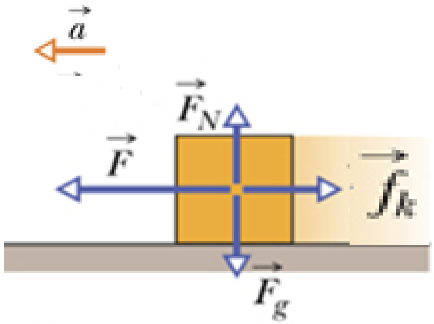
$$F = f_s$$



(d)

The body does not move

$$F = f_{s,\max}$$



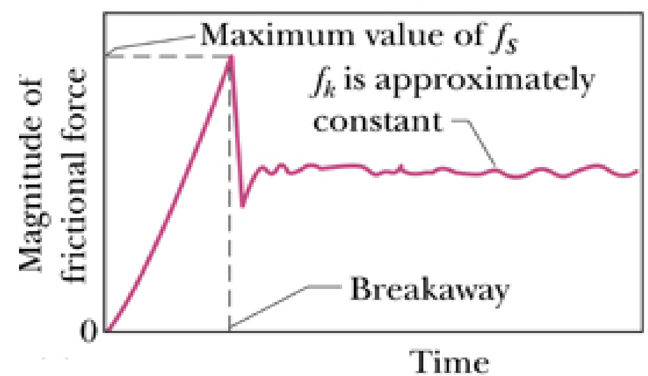
(e)

$$\vec{F} \succ \vec{f}_{s,\max}$$

*The body starts moving with acceleration

***The kinetic frictional force.**

$$f_k \prec f_{s,\max}$$



6-3 | Properties of Friction

Property 1. If the body does not move, then the static frictional force $\vec{f}_s$ and the component of $\vec{F}$ that is parallel to the surface balance each other. They are equal in magnitude, and $\vec{f}_s$ is directed opposite that component of $\vec{F}$.

Property 2. The magnitude of $\vec{f}_s$ has a maximum value $f_{s,\max}$ that is given by

$$f_{s,\max} = \mu_s F_N,$$

where μ_s is the **coefficient of static friction** and F_N is the magnitude of the normal force on the body from the surface.

Property 3. If the body begins to slide along the surface, the magnitude of the frictional force rapidly decreases to a value f_k given by

$$f_k = \mu_k F_N$$

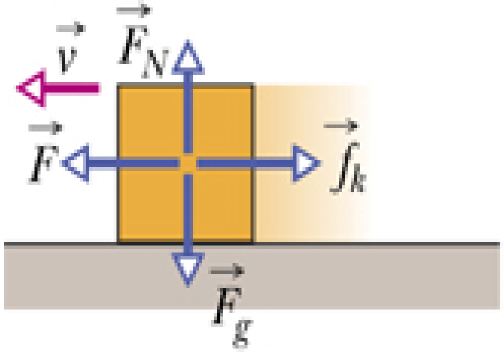
where μ_k is the **coefficient of kinetic friction.**

μ_s : Cofficient of static friction.

μ_k : Cofficient of kinetic friction.

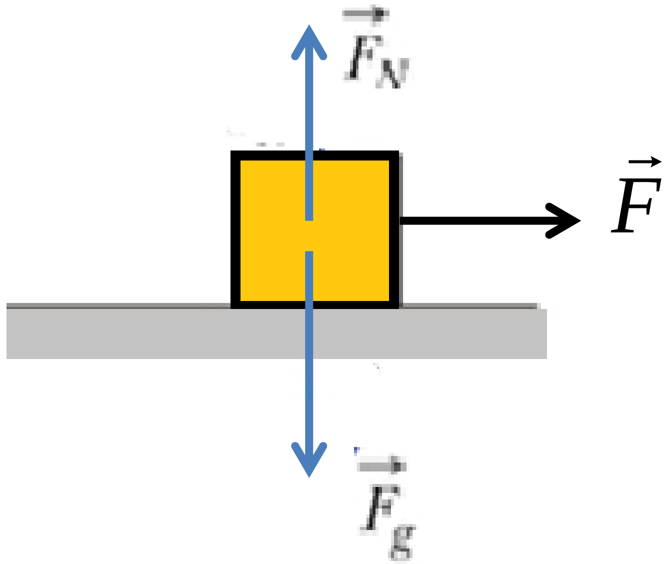
- They are dimensionless.
- Their values must be determined experimentally.
- Their values depend on the properties of the body and the surface.

If the body starts moving with **constant velocity** what is the magnitude of kinetic frictional force?



$$\boxed{\begin{aligned} F_{net,x} &= 0 \\ -F + f_k &= 0 \\ F &= f_k \end{aligned}}$$

How you can make this block move, given the mass of the block and μ_s ?



$$f_{s,\max} = \mu_s F_N$$

$$\boxed{F \succ f_{s,\max}}$$

$$F_{net,y} = 0$$

$$F_n - F_g = 0$$

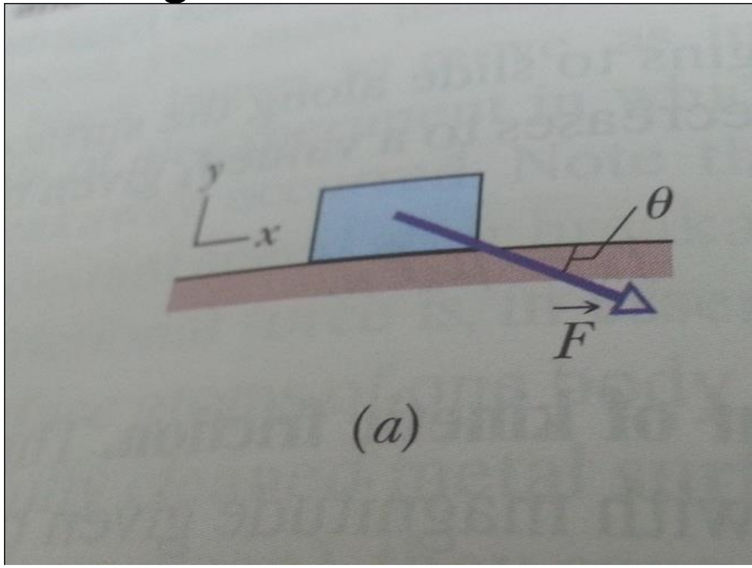
$$F_n = F_g = mg$$

$$f_{s,\max} = \mu_s mg$$

$$\boxed{F \succ \mu_s m g}$$

Sample Problem 6.01 Angled force applied to an initially stationary block

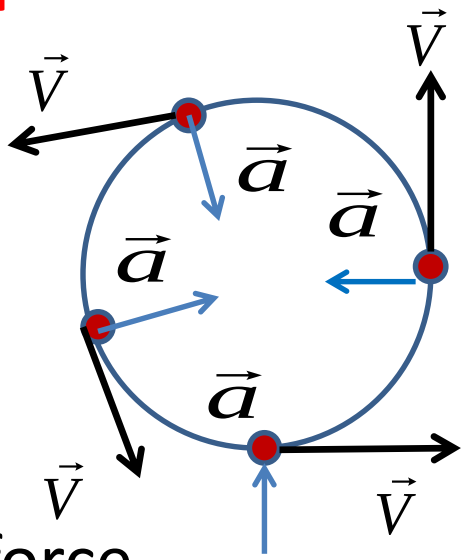
Figure (6-3 a) shows a force of magnitude F = 12 N applied to an 8.00 kg block at a downward angle of θ = 30.0 °. The coefficient of static friction between block and floor is μ_s = 0.700 , the coefficient of kinetic friction is μ_k = 0.400. Does the block begin to slide or does it remain stationary? What is the magnitude of the frictional force on the block?



(a)

6-5 | Uniform Circular Motion

A particle is in uniform circular motion if it travels Around a circle or circular arc at **constant speed.**

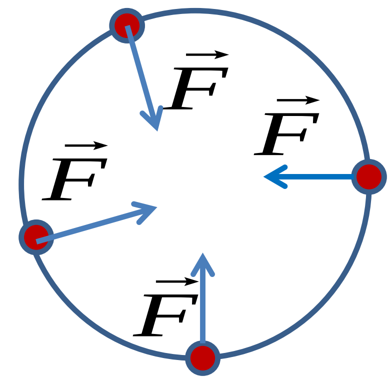


If we apply Newton's second law to analyze uniform circular motion we conclude that:

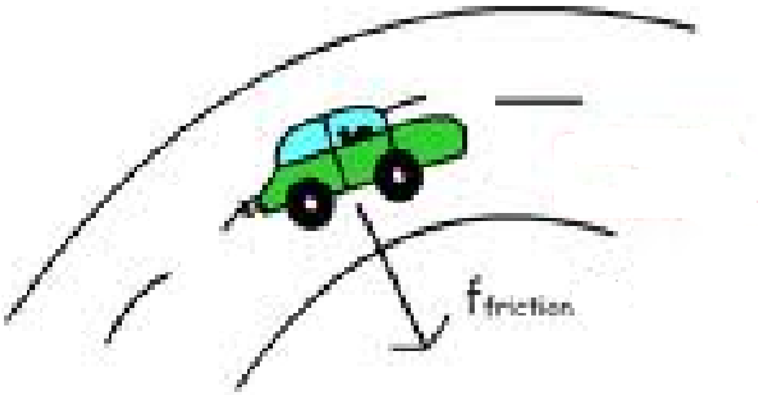
There is an acceleration $\Rightarrow$ there must be a force produced that acceleration.

- magnitude : $F = ma = m\dfrac{v^2}{r}$
- direction: toward the center.
- It is called **Centripetal Force.**

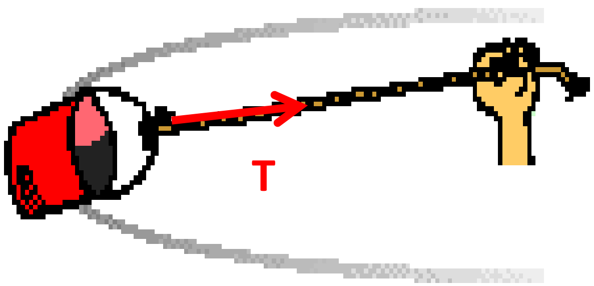
A centripetal force accelerates a body by changing the direction of the body's velocity without changing the body's speed.



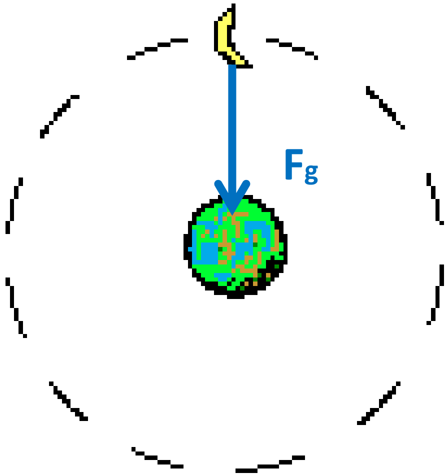
Centripetal force is **not** a new kind of force. It is simply the **net force** that points from the rotating body to the rotation center . Depending on the situation the centripetal force can be friction, tension, or gravity.



Friction Force is the centripetal force



Tension Force is the centripetal force



Gravity Force is the centripetal force

Problem 57p125

A puck of mass m = 1.50 kg slides in a circle of radius r = 25.0 cm on a frictionless table while attached to a hanging cylinder of mass M = 2.50 kg by means of a cord that extends through a hole in the table (Fig. 6-45). What speed keeps the cylinder at rest?

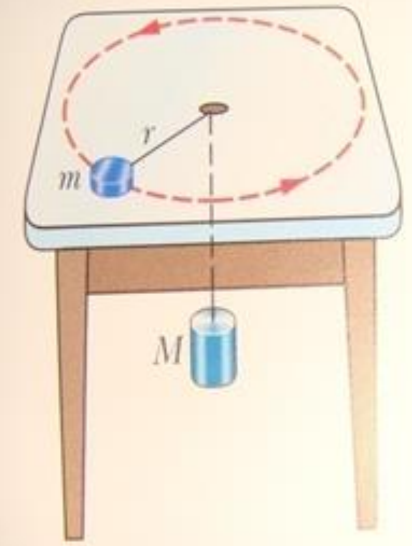
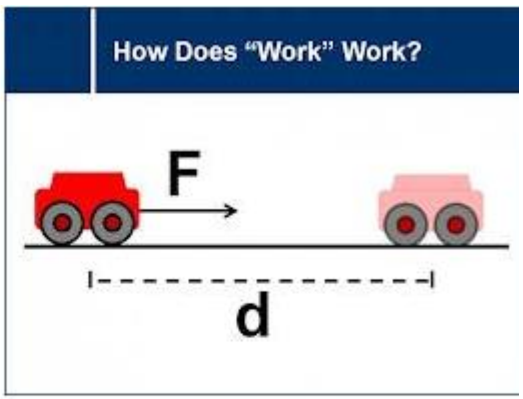
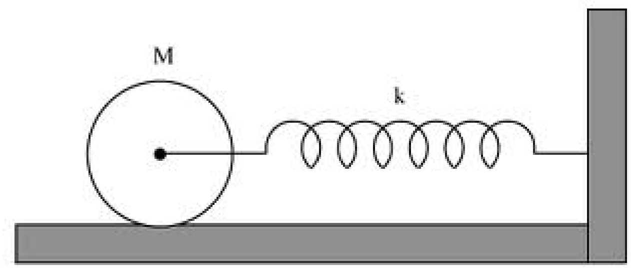


Figure 6-45
Problem 57.

THE END.

7 Kinetic Energy and Work





By Dr. Wajood Diery

7.1 kinetic Energy

What is energy?

kinetic Energy

We define a new physical parameter to describe the state of motion of an object of mass m and speed v. We define its kinetic energy K as

$$\boxed{K = \frac{mv^2}{2}.}$$

SI unit is joule, symbol: **J** . $1 \text{ joule} = 1 \text{ J} = 1 \text{ kg} \cdot \text{m}^2/\text{s}^2$

Problem 1 page 147

When accelerated along a straight line at 2.8×10^{15} m/ s^2 in a machine, an electron (mass m= 9.1×10^{-31} kg) has an initial speed of 1.4×10^{7} m/ s and travels 5.8cm.

Find

(a) the final speed of the electron and

(b) the increase in its kinetic energy.

7.2 Work and kinetic energy

Work W is energy transferred to or from an object by means of a force acting on the object. Energy transferred to the object is positive work, and energy transferred from the object is negative work.

If energy is transferred **to** the object $\Rightarrow$ work (W) is positive.

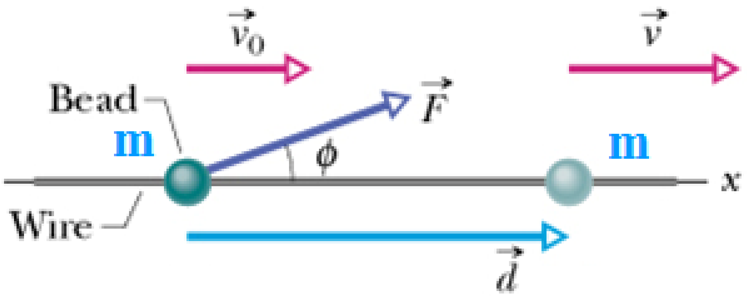
If energy is transferred **from** the object $\Rightarrow$ work $(W < 0)$ is negative.

Work has the SI unit of the joule, the same as kinetic energy

Finding an Expression for Work

$$W = Fd\cos\phi \qquad \text{(work done by a constant force)}$$

$$W = \vec{F}\cdot\vec{d}$$



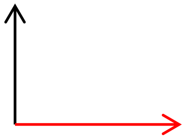
- Work has another unit

$$1\ \text{J} = 1\ \text{kg}\cdot\text{m}^2/\text{s}^2 = 1\ \text{N}\cdot\text{m} = 0.738\ \text{ft}\cdot\text{lb}.$$

$$W = Fd\cos\phi \qquad \text{(work done by a constant force)}$$

$$1\text{- If the angle } \phi \text{ between the force and displacmen} = 0^0 \Rightarrow W = Fd$$

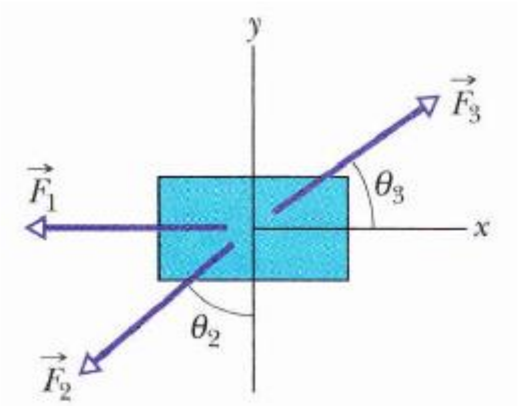
$$3\text{- If the angle } \phi \text{ between the force and displacmen} = 90^0 \Rightarrow W = 0$$



$$5\text{- If the angle } \phi \text{ between the force and displacmen} = 180^0 \Rightarrow W = -Fd$$

How to find the net Work done by several forces?

Net work done by several forces.



Find the work done by each force and then sum those works

$$W_1 = F_1 d$$

$$W_2 = F_2 d$$

$$W_3 = F_3 d$$

$$W_{net} = W_1 + W_2 + W_3 + \cdots$$

Find the net forc $\vec{F}_{net}$ then

$$W_{net} = (F_{net}) d \cos\phi,$$

$where\ \phi\ is\ the\ angle\ between\ \vec{F}_{net}\ and\ \vec{d}$

Net Work: If we have several forces acting on a body there are two methods that can be used to calculate the net work W_{net}

Method 1: First calculate the work done by each force: W_A by force $\vec{F}_A$, W_B by force $\vec{F}_B$, and W_C by force $\vec{F}_C$. Then determine $W_{\text{net}} = W_A + W_B + W_C$.

Method 2: Calculate first $\vec{F}_{\text{net}} = \vec{F}_A + \vec{F}_B + \vec{F}_C$; then determine $W_{\text{net}} = \vec{F}_{\text{net}} \cdot \vec{d}$.

Work-Kinetic Energy Theorem

$$\boxed{\Delta K = K_f - K_i = W_{\text{net}}}$$

$$W_{\text{net}} = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mv_0^2$$

$$\begin{bmatrix} \text{Change in the kinetic} \\ \text{energy of a particle} \end{bmatrix} = \begin{bmatrix} \text{net work done on} \\ \text{the particle} \end{bmatrix}$$

If $W_{\text{net}} > 0 \rightarrow K_f > K_i$ $\Rightarrow$ **Energy increases**

If $W_{\text{net}} < 0 \rightarrow K_f < K_i$ $\Rightarrow$ **Energy decreases**

Sample Problem 7.02

Figure 7-4*a* shows two industrial spies sliding an initially stationary 225 kg floor safe a displacement $\vec{d}$ of magnitude 8.50 m, straight toward their truck. The push $\vec{F}_1$ of spy 001 is 12.0 N, directed at an angle of 30.0° downward from the horizontal; the pull $\vec{F}_2$ of spy 002 is 10.0 N, directed at 40.0° above the horizontal. The magnitudes and directions of these forces do not change as the safe moves, and the floor and safe make frictionless contact.

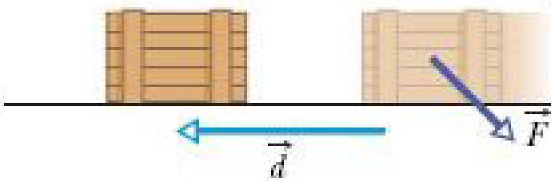
(a) What is the net work done on the safe by forces $\vec{F}_1$ and $\vec{F}_2$ during the displacement $\vec{d}$?

(b) During the displacement, what is the work W_g done on the safe by the gravitational force $\vec{F}_g$ and what is the work W_N done on the safe by the normal force $\vec{F}_N$ from the floor?

(c) The safe is initially stationary. What is its speed v_f at the end of the 8.50 m displacement?

Sample Problem 7.03

During a storm, a crate of crepe is sliding across a slick, oily parking lot through a displacement $\vec{d} = (-3.0\text{ m})\hat{\text{i}}$ while a steady wind pushes against the crate with a force $\vec{F} = (2.0\text{ N})\hat{\text{i}} + (-6.0\text{ N})\hat{\text{j}}$. The situation and coordinate axes are shown in Fig. 7-5.



(a) How much work does this force do on the crate during the displacement?

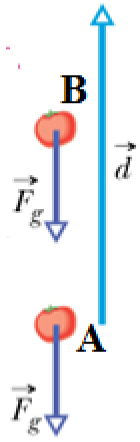
(b) If the crate has a kinetic energy of 10 J at the beginning of displacement $\vec{d}$, what is its kinetic energy at the end of $\vec{d}$?

7-3 Work done by the gravitational force

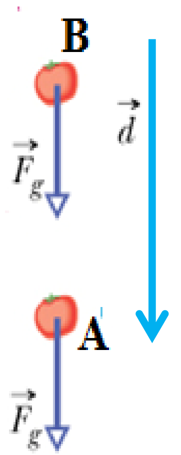
$$W_g = mgd\cos\phi \qquad \text{(work done by gravitational force)}$$

For a rising object, force $\vec{F}_g$ is directed opposite the displacement $\vec{d}$.

$$W_g = mgd\cos 180° = mgd(-1) = -mgd.$$



For falling object, force $\vec{F}_g$ is directed along the displacement $\vec{d}$



$$W_g = mgd\cos 0° = mgd(+1) = +mgd$$

Problem 18 p. 148

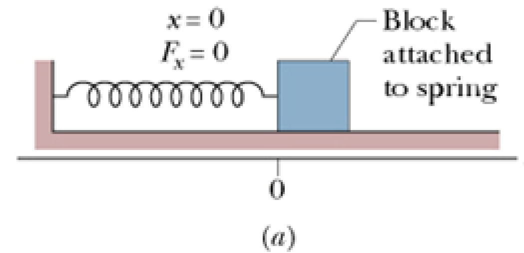
In 1975 the roof of Monteria's Velodrome, with a weight of 360 kN, was lifted by 10 cm so that it could be centered.

-How much work was done on the roof by the forces making the lift?

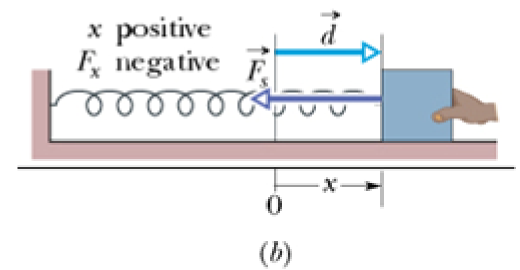
7-4 Work done by a spring force

The Spring Force

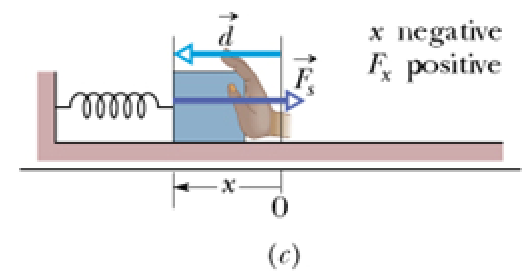
Fig. a shows a spring in its relaxed state.



In fig. b we pull one end of the spring and stretch it by an amount d. The spring resists by exerting a force F on our hand in the opposite direction.



In fig. c we push one end of the spring and compress it by an amount d. Again the spring resists by exerting a force F on our hand in the opposite direction.



The *spring force* is given by

$$\vec{F}_s = -k\vec{d} \qquad \text{(Hooke's law)}$$

$$\vec{F}_s = -k\vec{d} \qquad \text{(Hooke's law)}$$

- The minus sign in Eq. 7-20 indicates that the direction of the spring force is always opposite the direction of the displacement of the spring
- The constant k is called the **spring constant** (or **force constant**)
- The SI unit for k is the newton per meter.

$$d = x_2 - x_1 \ , \ Let \ x_1 = 0 \ and \ x_2 = x$$

$$\boxed{F_x = -kx \qquad \text{(Hooke's law)}}$$

The Work Done by a Spring Force

$$\boxed{W_s = \tfrac{1}{2}kx_i^2 - \tfrac{1}{2}kx_f^2}$$

$- \text{If } x_i \succ x_f \Leftarrow W + ve$

$- \text{If } x_f \succ x_i \Leftarrow W - ve$

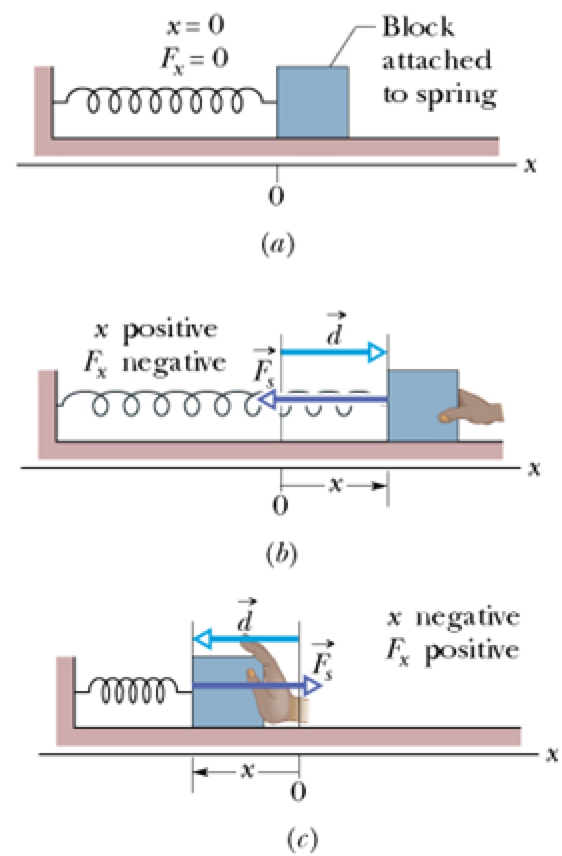
Work W_s is positive if the block ends up closer to the relaxed position ($x = 0$) than it was initially. It is negative if the block ends up farther away from $x = 0$. It is zero if the block ends up at the same distance from $x = 0$.

If $x_i = 0$ and if we call the final position x

$$\boxed{W_s = -\tfrac{1}{2}kx^2}$$

Problem 27 p. 149

A spring and block are in the arrangement of Fig. 7-10 when the block is pulled out to x=+4.0 cm, we must apply a force of magnitude 360 N to hold it there. We pull the block to x=11 cm and then release it. How much work does the spring do on the block as the block moves from xi =+5.0 cm to (a) x = +3.0 cm, (b) x = -3.0 cm, (c) x= -5.0 cm, and (d) x= -9.0 cm ?



7-6 Power

The time rate at which work is done by a force is said to be the **power**

Average power

$$P_{avg} = \frac{W}{\Delta t} \qquad \text{(average power).}$$

Instantaneous power

$$P = \frac{dW}{dt} \qquad \text{(instantaneous power).}$$

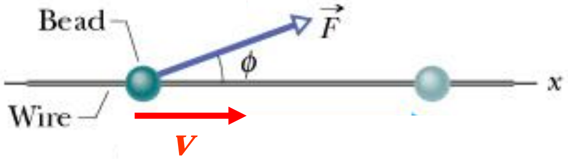
Unit of P : The SI unit of power is the watt. It is defined as the power of an engine that does work $W = 1$ J in a time $t = 1$ second.

A commonly used non-SI power unit is the horsepower (hp), defined as

1 hp = 746 W.

The kilowatt-hour The kilowatt-hour (kWh) is a unit of work. It is defined as the work performed by an engine of power $P = 1000$ W in a time $t = 1$ hour, $W = Pt = 1000 \times 3600 = 3.60 \times 10^6$ J. The kWh is used by electrical utility companies (check your latest electric bill).

$$P = \frac{dW}{dt} \quad \text{but} \quad W = Fd\cos\phi$$



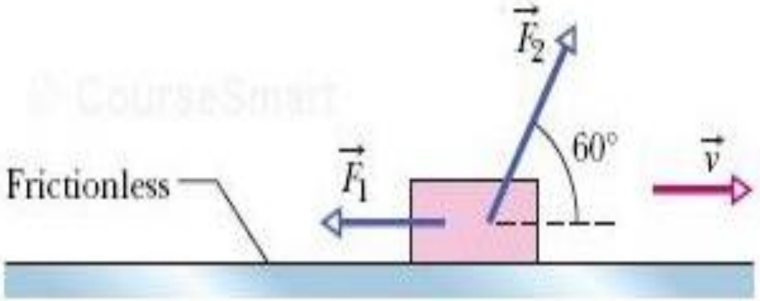
$$= \frac{d\,F\cos\phi\,dx}{dt}$$

$$= F\cos\phi\left(\frac{dx}{dt}\right) \Rightarrow \boxed{P = Fv\cos\phi}$$

$$\boxed{P = \vec{F}\cdot\vec{v}}$$

Sample Problem 7.09

Figure 7-16 shows constant forces $\vec{F}_1$ and $\vec{F}_2$ acting on a box as the box slides rightward across a frictionless floor. Force $\vec{F}_1$ is horizontal, with magnitude 2.0 N; force $\vec{F}_2$ is angled upward by 60° to the floor and has magnitude 4.0 N. The speed v of the box at a certain instant is 3.0 m/s. What is the power due to each force acting on the box at that instant, and what is the net power? Is the net power changing at that instant?

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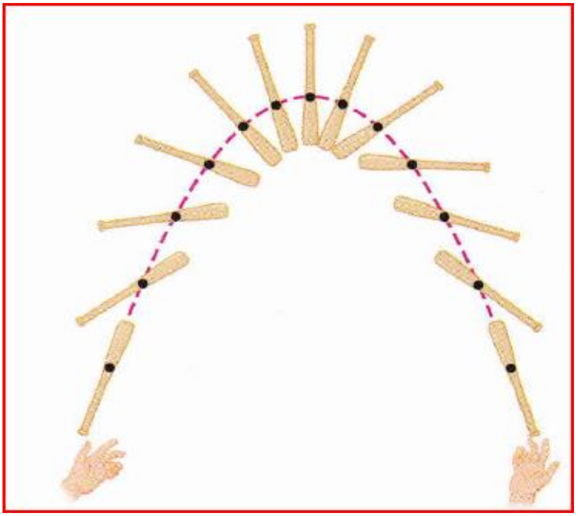
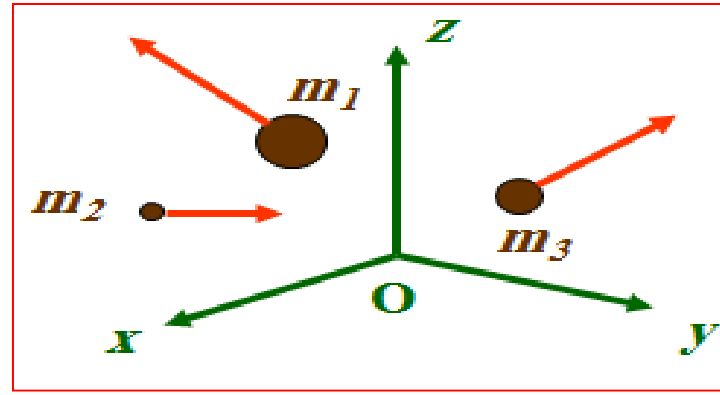
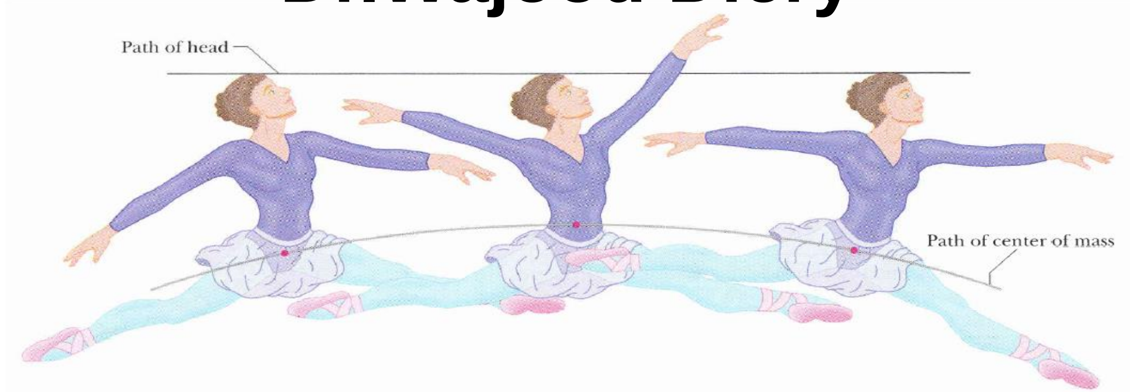




Center of Mass and Linear Momentum 9

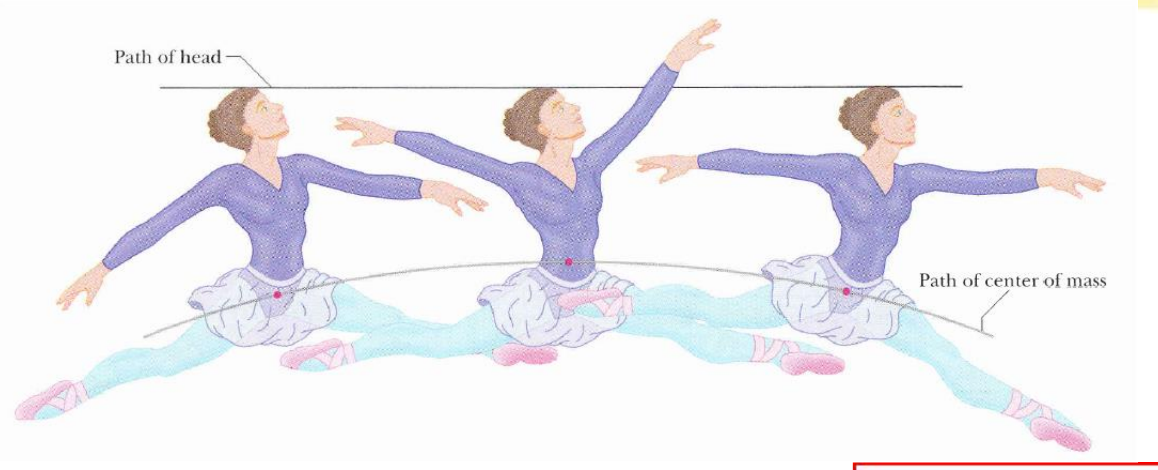
Dr.Wajood Diery

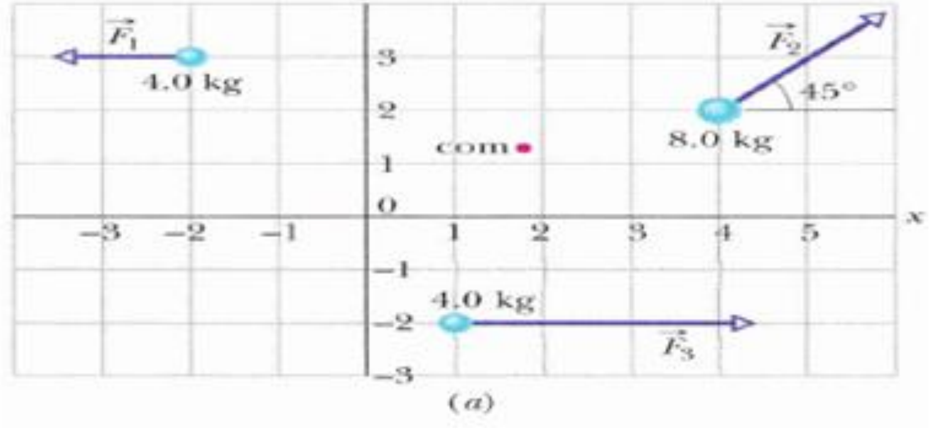


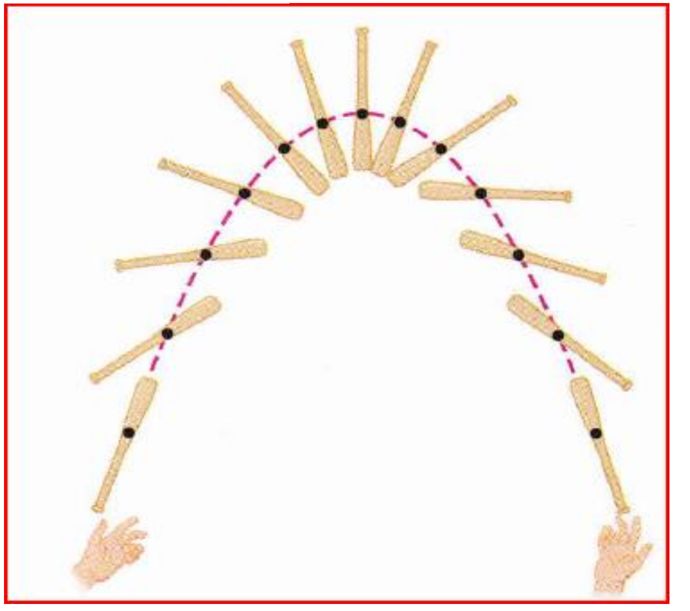
9-1 Center of Mass

Q. What is the Centre Of Mass (COM)?

The center of mass of a system of particles is the point that moves as though (1) all of the system's mass were concentrated there and (2) all external forces were applied there.







The Center of Mass

1. System of two particles on x-axis

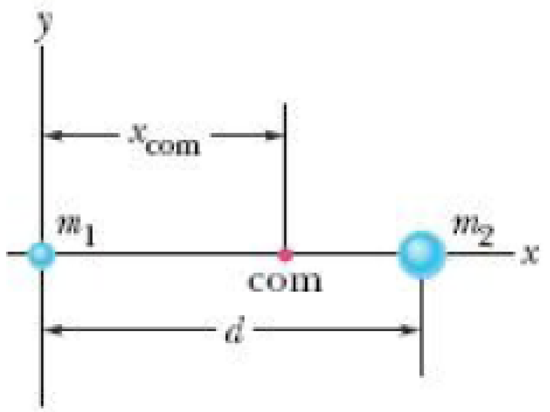
$$x_{com} = \frac{m_2}{m_1 + m_2} d$$

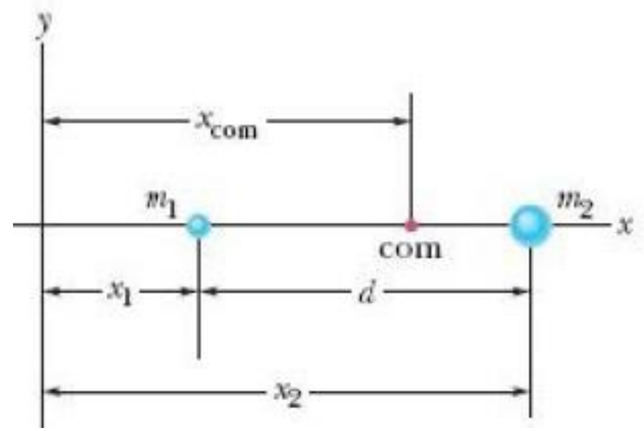
$$\boxed{x_{com} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}}$$

$$\boxed{x_{com} = \frac{m_1 x_1 + m_2 x_2}{M}}$$

Where $M = m_1 + m_2.$

and x_1 , x_2 are the position of particles m_1 and m_2 respectively from the origin





2. System of n particles along x- axis:

$$x_{com} = \frac{m_1x_1 + m_2x_2 + m_3x_3 + \cdots + m_nx_n}{M}$$

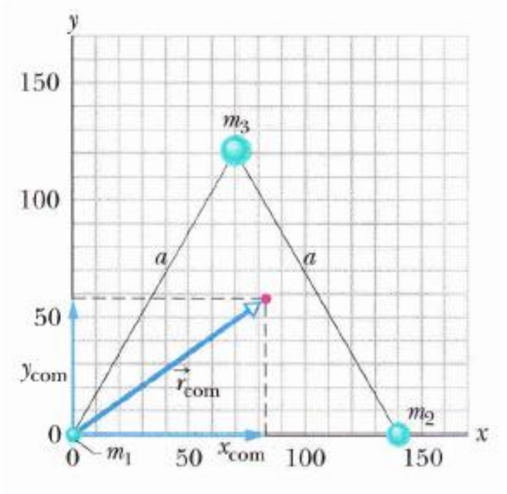
$$= \frac{1}{M}\sum_{i=1}^{n} m_i x_i.$$

Rem: put x_1 , x_2 ....etc, with their signs

3. System of n particles distributed in 3D:

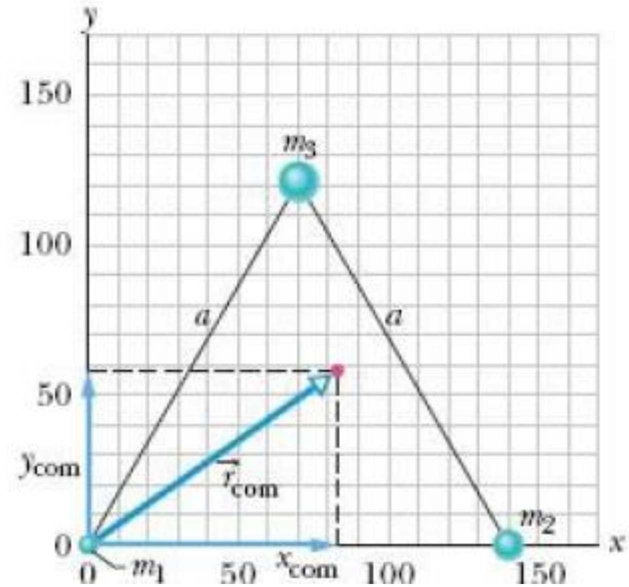
$$x_{com} = \frac{1}{M}\sum_{i=1}^{n} m_i x_i, \qquad y_{com} = \frac{1}{M}\sum_{i=1}^{n} m_i y_i, \qquad z_{com} = \frac{1}{M}\sum_{i=1}^{n} m_i z_i.$$

$$\vec{r}_{com} = x_{com}\hat{\mathrm{i}} + y_{com}\hat{\mathrm{j}} + z_{com}\hat{\mathrm{k}}.$$



Sample Problem 9.01

Three particles of masses $m_1 = 1.2$ kg, $m_2 = 2.5$ kg, and $m_3 = 3.4$ kg form an equilateral triangle of edge length $a = 140$ cm. Where is the center of mass of this system?



(9-3)

9-2 Newton's Second Law for a System of Particles

$$\vec{F}_{net} = M\vec{a}_{com}$$

1. $\vec{F}_{net}$ is the net force of *all external forces* that act on the system.

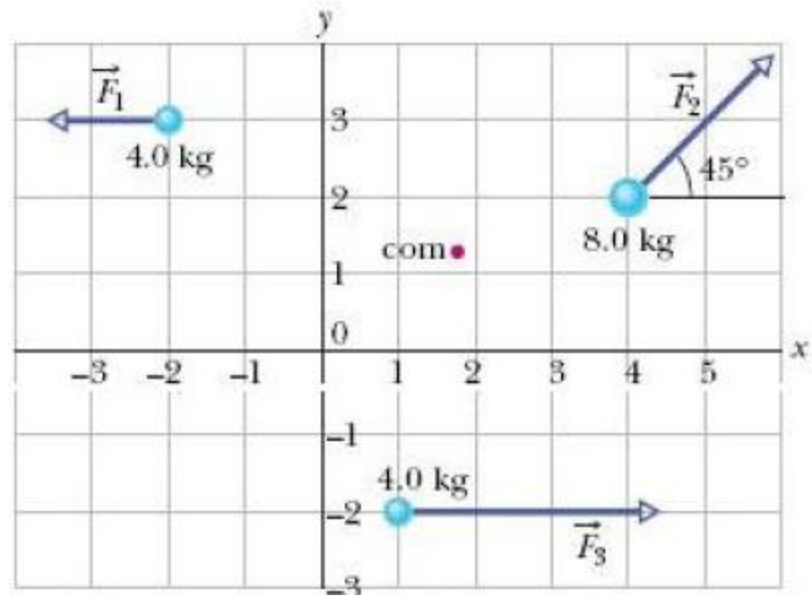
2. M is the *total mass* of the system. We assume that no mass enters or leaves the system as it moves, so that M remains constant. The system is said to be **closed.**

3. $\vec{a}_{com}$ is the acceleration of the *center of mass* of the system.

$$F_{net,x} = Ma_{com,x} \qquad F_{net,y} = Ma_{com,y} \qquad F_{net,z} = Ma_{com,z}$$

Sample Problem 9.03

The three particles in Fig. 9-7*a* are initially at rest. Each experiences an *external* force due to bodies outside the three-particle system. The directions are indicated, and the magnitudes are $F_1 = 6.0$ N, $F_2 = 12$ N, and $F_3 = 14$ N. What is the acceleration of the center of mass of the system, and in what direction does it move?



(a) Fig. (9-7)

9-3 Linear Momentum

Linear Momentum of a single particle

Linear Momentum of a system of particles

Linear Momentum of a single particle

$$\vec{p} = m\vec{v}$$

- $\vec{p}$ is a vector quantity
- SI unit is $(\mathrm{kg} \cdot \mathrm{m/s})$.

Newton's 2nd Law in terms of Momentum

The time rate of change of the momentum of a particle is equal to the net force acting on the particle and is in the direction of that force.

In equation form $\boxed{\vec{F}_{\text{net}} = \dfrac{d\vec{p}}{dt}.}$

$$\vec{F}_{\text{net}} = \frac{d\vec{p}}{dt} = \frac{d}{dt}(m\vec{v}) = m\frac{d\vec{v}}{dt} = m\vec{a}.$$

Thus, the relations $\vec{F}_{\text{net}} = d\vec{p}/dt$ and $\vec{F}_{\text{net}} = m\vec{a}$ are equivalent expressions of Newton's second law of motion for a particle.

Linear Momentum of a system of particles

$$\vec{P} = \vec{p}_1 + \vec{p}_2 + \vec{p}_3 + \cdots + \vec{p}_n$$

$$= m_1\vec{v}_1 + m_2\vec{v}_2 + m_3\vec{v}_3 + \cdots + m_n\vec{v}_n.$$

$$\boxed{\vec{P} = M\vec{v}_{\text{com}}}$$

The linear momentum of a system of particles is equal to the product of the total mass M of the system and the velocity of the center of mass.

If we take the time derivative $$\frac{d\vec{P}}{dt} = M\frac{d\vec{v}_{\text{com}}}{dt} = M\vec{a}_{\text{com}}.$$

9-5 Conservation of Linear Momentum

The system is said to be

Isolated: When the net external forces acting on a system of particles is zero

Closed: When no particles leave or enter the system

then $\vec{F}_{net} = 0$

$$\vec{F}_{net} = \frac{d\vec{p}}{dt} = 0$$

then $\vec{P} = \text{constant}$ (closed, isolated system).

In words,

If no net external force acts on a system of particles, the total linear momentum $\vec{P}$ of the system cannot change.

$$\vec{P} = \text{constant} \qquad \text{(closed, isolated system).}$$

This result is called the **law of conservation of linear momentum.** It can also be written as

$$\vec{P}_i = \vec{P}_f \qquad \text{(closed, isolated system).}$$

In words, this equation says that, for a closed, isolated system,

$$\begin{pmatrix}\text{total linear momentum}\\ \text{at some initial time } t_i\end{pmatrix} = \begin{pmatrix}\text{total linear momentum}\\ \text{at some later time } t_f\end{pmatrix}.$$

Rem:

Depending on the forces acting on a system, linear momentum might be conserved in one or two directions but not in all directions. However,

If the component of the net *external* force on a closed system is zero along an axis, then the component of the linear momentum of the system along that axis cannot change.

External Example

One-dimensional explosion: A ballot box with mass $m = 6.0$ kg slides with speed $v = 4.0$ m/s across a frictionless floor in the positive direction of an x axis. The box explodes into two pieces. One piece, with mass $m_1 = 2.0$ kg, moves in the positive direction of the x axis at $v_1 = 8.0$ m/s. What is the velocity of the second piece, with mass m_2?

THE END