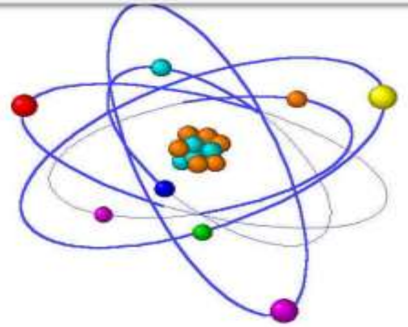
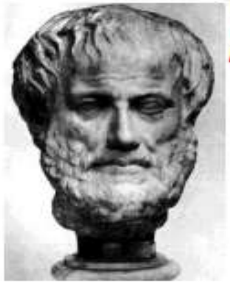
Lecture 1.
Overview of Basic Physics:
1 particle 1 dimension

23 August 2018

History of Physics

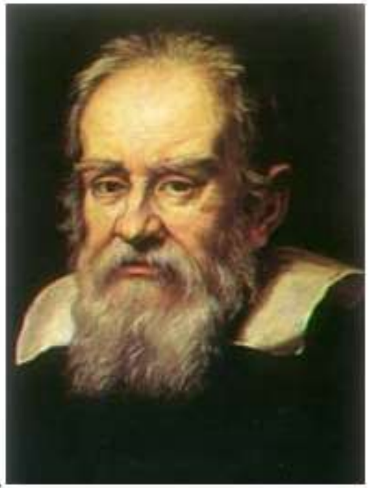


- The Greeks
  - Cultivated the study of “Natural Philosophy”



  Aristotle(384-322 BC)
    - Student of Plato
    - observation of physical phenomena → Physical Laws
    - Wrote first Physics book Aristotle’s Physics
    - Believed earth was center of solar system (geocentric)
- Knew earth was a sphere (Eratosthenes 276-194BC)
- Aristarchus proposed sun centered (heliocentric) model of solar system
- Archimedes made many contributions in fluids and mechanics
- Ptolemy wrote many scientific “papers” which became basis for later advancement
- Greeks developed scientific method
- Most of Greek work was lost. Some was salvaged through Islamic philosphers who reinterpreted the Greek in the context of their religion.

Galileo Galilei-The Rise of Physics and mathematics



- Knowledge was dominated by Law, medicine and theology
- Galileo studied Copernicus and felt that math was the key to understanding the motion of the planets.
- Discovered moons of Jupiter in 1609 (First telescope?)->big job->publications
- Dialogue Concerning the Two Chief Worlld Systems-> house arrest
- Galileo started new focus on experimentation-> start of a new age in science

Descartes-believed that motion was due to objects following the influence of corpuscles. Planetary motion was caused by vortex motion of corpuscles in space. Decartes did not believe that a vacuum could exist.

Isaac Newton-The Big Picture

http://en.wikipedia.org/wiki/Isaac_Newton

- 4 January 1643 – 31 March 1727
- Built first practical refracting telescope
- Developed a theory of colour, emperical law of cooling
- Co-inventor of Calculus and Generalized Binomial Theorem
- Published Principia 1687
    - Laid groundwork for classical mechanics
    - Law of Universal Gravitation
    - Newton's Three law's of Motion
    - Showed Kepler's laws came from law of Universal Gravitation
    - Saw the Big Picture!!
    - Principia dominated science for next three centuries!!

The Middle Years 1750-1900

- Calculus and mathematical analysis applied to many problems
- Mid 1800's , theories of the energy of physics were developed. These theories made physicists rethink how the physical world worked.
- James Clerk Maxwell (June 1831 –Nov 1879) led the way with his Kinetic Theory of gases and his theory of electromagnetic radiation
    - Showed EM radiation, light and magnetic fields were all products of the electromagnetic field-> second great unification!
    - These two discoveries laid down the groundwork for "Modern Physics" which was just around the corner!
- **Maxwell is considered to be as great a scientist as Newton and Einstein!**

Physics in 1900

The problems:

1. Blackbody Radiation
2. Photoelectric Effect
3. Certain types of radioactivity could not be explained
4. An ether around the earth through which EM radiation was postulated to travel could not be found.

Einstein and Quantum Mechanics

1. Special Theory of Relativity which gave mass-energy equivalence($E=mc^2$)
2. Postulated that light could be a particle which was **quantized(E=hf).** This was a revolutionary idea!
   - Neils Bohr used this idea to explain the hydrogen atom and the light frequencies emitted by hydrogen gas. This was the beginning of Quantum Mechanics.
   - This explained the Photoelectric Effect
3. Einstein's General Theory of Relativity showed that the force of gravity and motion in an accelerating frame are indistinguishable.

Homework: Look at THIS VIDEO

Quantum Mechanics-The Roaring 20's

1. Bohr's idea was expanded to full scale theory in 1920's.
2. Debroglie(1925)(showed that light could behave as a wave(particle-wave duality)
3. Heisenberg's Uncertainty Principle (1927)showed that for very small things you can measure momentum or position but not both.
4. Paul Dirac produced relativistic quantum theory in 1928
5. Theories got more complicated but couldn't quite fit known results.
6. Einstein did not like the probabilistic nature of quantum mechanics and said "I do not believe that God plays dice?"

What happened next….

- Quantum mechanics evolved and cumulated
- in the late 1940s in the quantum electrodynamics (QED) of Rich Feyman,Freeman Dyson, Julian Schwinger and Si-ItiroTomonaga. Feynman, Schwinger and Tomonaga received the 1965 Nobel Prize in Physics. QED, a quantum theory of electrons, positrons, and the electromagnetic field, was the first satisfactory quantum description of a physical field and of the creation and annihilation of quantum particles. It was called Theory of everything!
- Particle physics evolved. Key features were the existance of short lived virtual particles governed by the Uncertainty Principle. Particles from nothing!
- Feyman was one of the great minds of science
- http://en.wikipedia.org/wiki/Richard_Feynman
- Feynman explaining Atoms
- The Pleasure Of Finding Things Out(Part1)
- The Pleasure Of Finding Things Out(Part2))

What keeps protons in nucleus together? Repulsive force is very strong!

- Yukawa predicted existence of a powerful but short range force carried by a particle called a Pion whose size was bigger than an electron but smaller than a proton. Pion was discovered in 1947 as were many particles such as the neutron and positron.
- Particle accelerators built to search for new particles

Stanford Linear Accelerator

- Murray Gell-Mann and Zweig proposed that protons, neutrons were composed of smaller particles called quarks. It is impossible to see a free quark!
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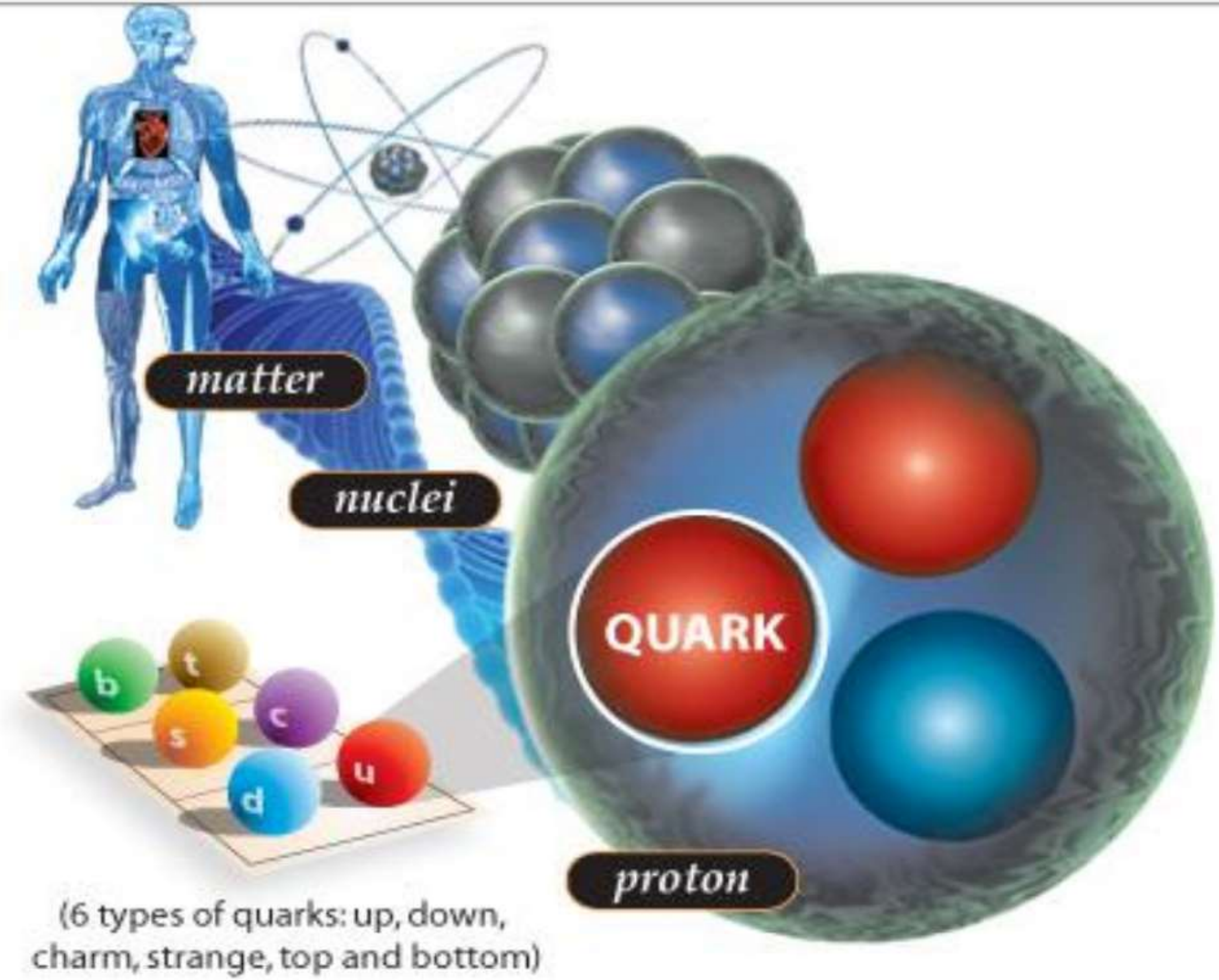
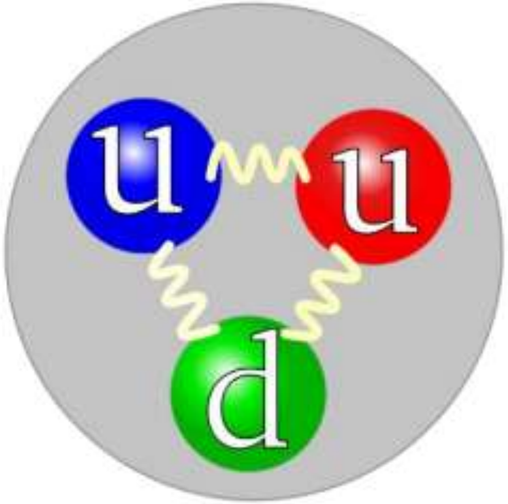

matter
nuclei
QUARK
proton
b
t
c
s
u
d
(6 types of quarks: up, down,
charm, strange, top and bottom)

•Standard Model-Quantum Chromodynamics



- The Standard Model was finalized in the 1970's which tied together all forces except for gravity.
- Particle accelerators have confirmed most parts of this model
- A theory called string theory holds promise to bring gravity into the fold. This theory requires strings of size much smaller than anything we know and 11 dimensions! These strings vibrate
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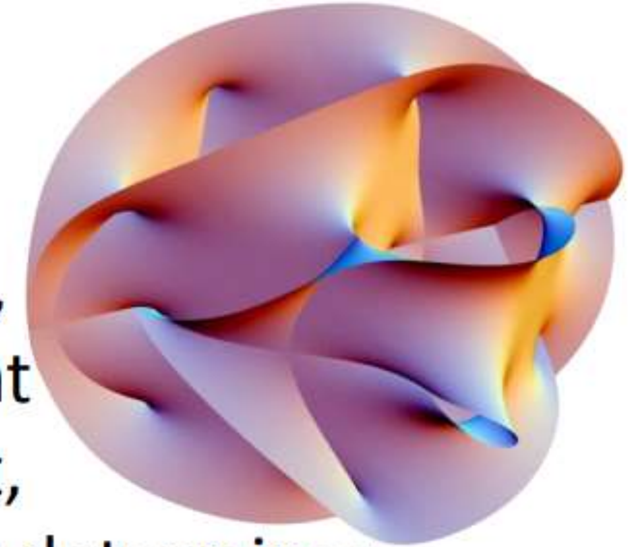
Strings become Membranes



- These "strings" vibrate in multiple dimensions, and depending on how they vibrate, they might be seen in 3-dimensional space as matter, light, or gravity. It is the vibration of the string which determines whether it appears to be matter or energy, and every form of matter or energy is the result of the vibration of strings.
- Five string theories by late 80’s
- M-theory incorporated all 5 string theories. Looks like a very good theory.
-

Free Fall

Free fall is a good example for one dimensional problems

Gravity:

- Things accelerate towards earth with a constant acceleration
- $a = g = 9.8 m/s^2$ towards the earth
- We'll come back to Gravity a lot!

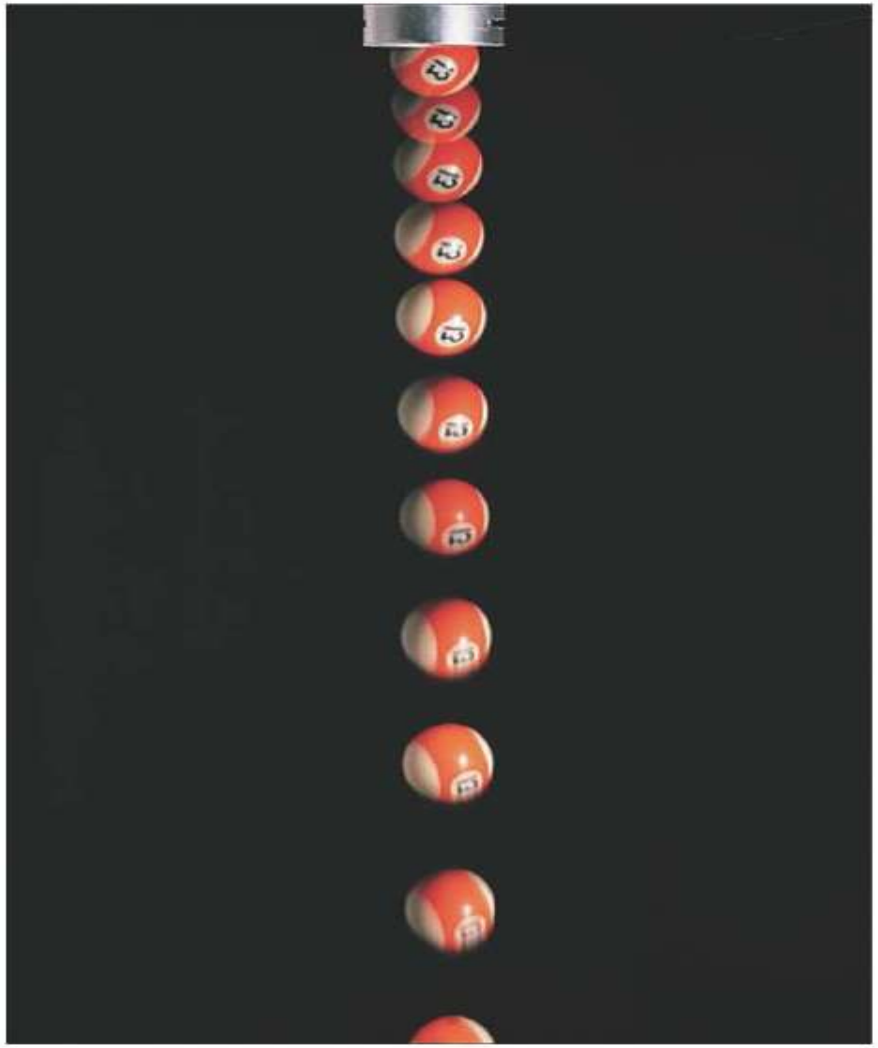
Free fall

Whenever an object is released in the air the acceleration is constant and pointing downwards.

The magnitude is $g=9.8\ m/s^2$. This is also known as the acceleration due to gravity, sometimes called simply gravity.

$$a_y=-9.8\ m/s^2=-g$$

NOTE: it does not matter which way the initial velocity is pointing (up or down), the acceleration is always downwards!!



Throw a Ball up

You throw a ball upward into the air with initial velocity V_0. Calculate:

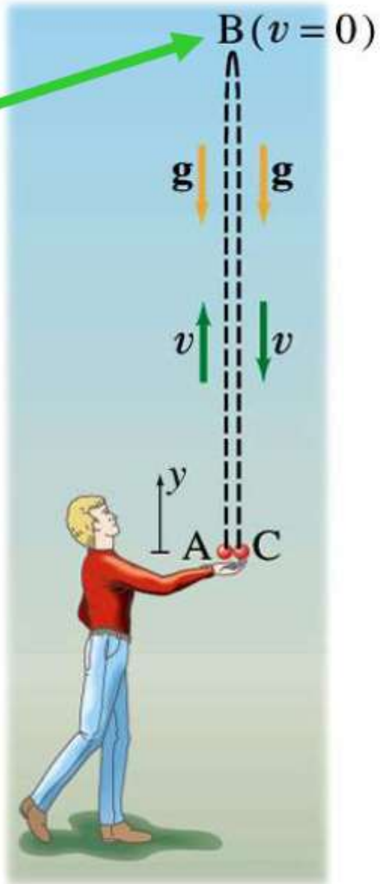
a) The time it takes to reach its highest point (the top).

b) Distance from your hand to the top

c) Time to go from your hand and come back to your hand

d) Velocity when it reaches your hand

e) Time from leaving your hand to reach some random height h.



Throw a Ball up

You throw a ball upward into the air with initial velocity V_0.
Calculate:

a) The time it takes to reach its highest point (the top).

1st and 2nd step

$y - y_0 =$

$v = 0$ → Key is to realize that v=0 at the top

$v_0 = v_0$

$a = -g$

$t = ?$

3rd step

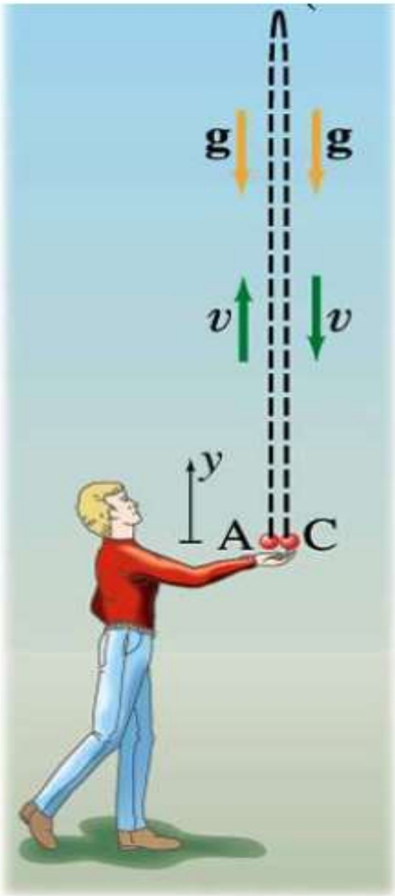
Which equation contains the three unknowns and the one we want?

$$y - y_0 = +v_0 t + \tfrac{1}{2}at^2$$

$$\boxed{v = v_0 + at}$$

$$v^2 = v_0^2 + 2a(y - y_0)$$

$$0 = v_0 + (-g)t \rightarrow t = \frac{v_0}{g}$$



Throw a Ball up

You throw a ball upward into the air with initial velocity V_0. Calculate:

b) Distance from your hand to the top

1st and 2nd step

$y - y_0 = h = ?$

$v = 0$ → Key is to realize that v=0 at the top

$v_0 = v_0$

$a = -g$

$t =$

3rd step

Which equation contains the three unknowns and the one we want?

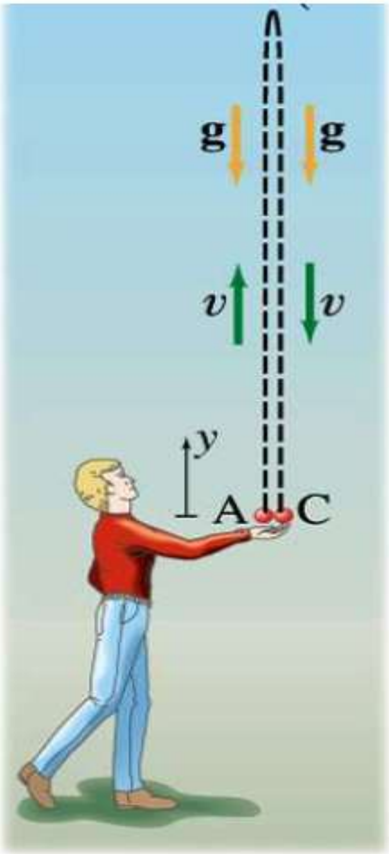
$$y - y_0 = +v_0 t + \tfrac{1}{2} a t^2$$

$$v = v_0 + at$$

$$v^2 = v_0^2 + 2a(y - y_0)$$

$$0^2 = v_0^2 + 2(-g)(h)$$

$$h = \frac{v_0^2}{2g}$$



Throw a Ball up

You throw a ball upward into the air with initial velocity V_0. Calculate:

c) Time it takes for the ball to come back to your hand

1st and 2nd step

$y - y_0 = 0$ → Key part

$v =$

$v_0 = v_0$

$a = -g$

$t = ?$

3rd step

Which equation contains the three unknowns and the one we want?

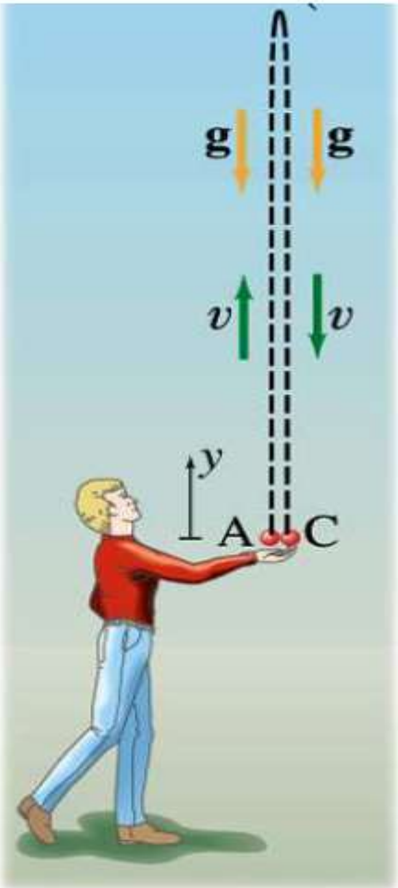
$$y - y_0 = +v_0 t + \tfrac{1}{2}at^2$$

$$v = v_0 + at$$

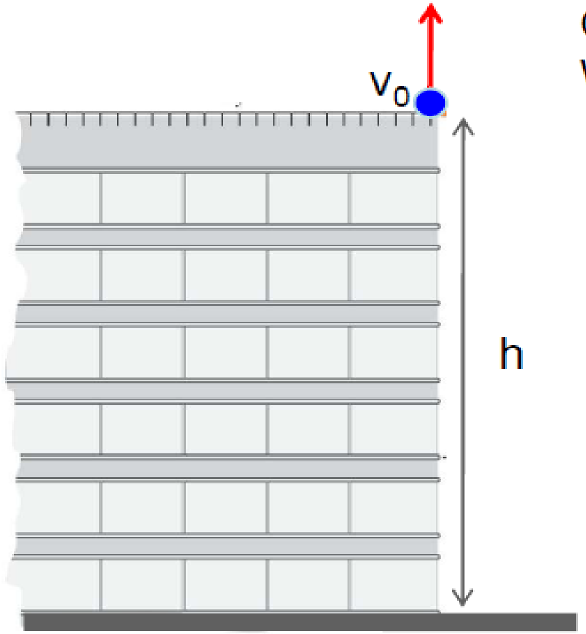
$$v^2 = v_0^2 + 2a(y - y_0)$$

$$0 = +v_0 t + \tfrac{1}{2}(-g)t^2 = t(v_0 - \tfrac{1}{2}gt)$$

$$\Rightarrow t = 0 \text{ and } t = \frac{2v_0}{g}$$



Free fall example



Q: A ball is thrown upwards with an initial velocity v_0. What is the speed of the ball when it hits the ground?

1st and 2nd step

$y - y_0 = -h$

$v = ?$

$v_0 = v_0$

$a = -g$

$t =$

3rd step

Which equation contains the three unknowns and the one we want?

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

$v = v_0 + at$

$v^2 = v_0^2 + 2a(y - y_0)$

$$v = \sqrt{v_0^2 + 2(-g)(-h)} = \sqrt{v_0^2 + 2hg}$$

Notice that solution does NOT depend on the sign of v_0

Q: A ball is thrown upwards with an initial velocity v_0. What is maximum height it gets from the top of the building?

This is a new problem. Start from the beginning b/c the end point is different!

1st and 2nd step

$y - y_0 = ?$

$v = 0$ → Key is to realize that v=0 at the top

$v_0 = v_0$

$a = -g$

3rd step

Which equation contains the three unknowns and the one we want?

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

$v = v_0 + at$

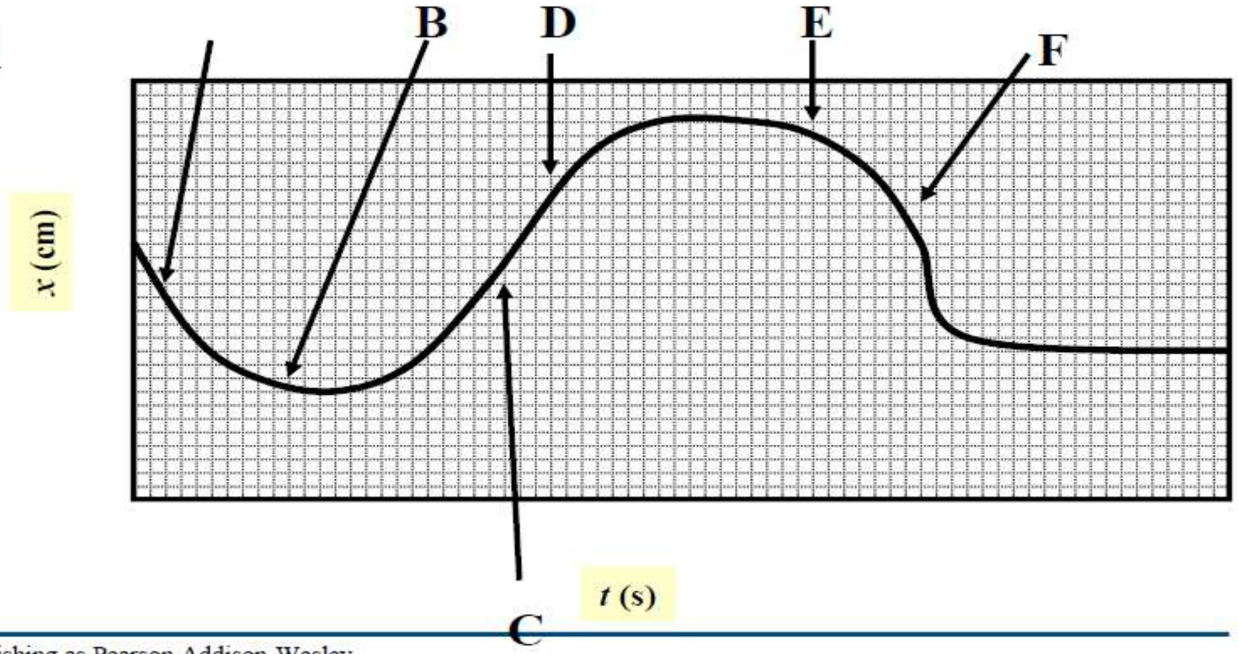
$v^2 = v_0^2 + 2a(y - y_0)$

$$(y - y_0) = \frac{0^2 - v_0^2}{2(-g)} = \frac{v_0^2}{2g}$$

Graphs

Describe motion in each point:

- Direction
- Velocity
- Acceleration



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Faculty of Science

60 YEARS MAHIDOL UNIVERSITY SCIENCE

Motion in Two or Three Dimensions

PowerPoint® Lectures for
University Physics, Twelfth Edition
– Hugh D. Young and Roger A. Freedman

Lectures by James Pazun

Firing up in the air at an angle

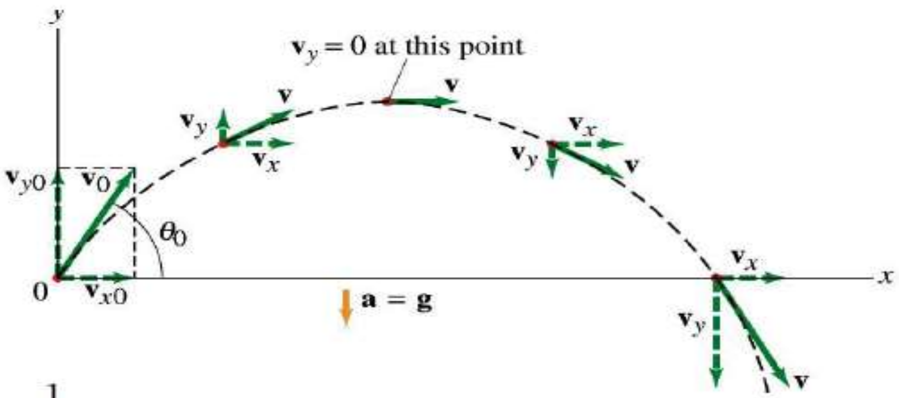
A ball is fired up with velocity V_o and angle ϑ_o. What is the range?

y-component

$$y - y_0 = 0$$
$$v_{0y} = v_0 \sin\theta$$
$$v_y =$$
$$a_y = -g$$
$$t =$$

x-component

$$x - x_0 = R = ?$$
$$v_x = v_0 \cos\theta$$
$$t =$$



Time of flight can be obtained by the x-component

$$x - x_0 = R$$
$$v_x = v_0 \cos\theta$$
$$t = \frac{R}{v_0 \cos\theta}$$

$$y - y_0 = v_{0y} t + \frac{1}{2} a_y t^2$$

$$0 = v_0 \sin\theta \left(\frac{R}{v_0 \cos\theta} \right) - \frac{1}{2} g \left(\frac{R}{v_0 \cos\theta} \right)^2$$

$$\tan\theta = \frac{1}{2} g \frac{R}{v_0^{\ 2} \cos\theta^2}$$

$$R = 2 \sin\theta \cos\theta \frac{v_0^{\ 2}}{g} = \sin(2\theta) \frac{v_0^{\ 2}}{g}$$

Kick a football

A football is kicked at angle Θ_0 with respect to the ground with speed V_0. Calculate:

a) The maximum height

b) The velocity at the maximum height

c) The time of travel before the football hits the ground

d) How far away it hits the ground

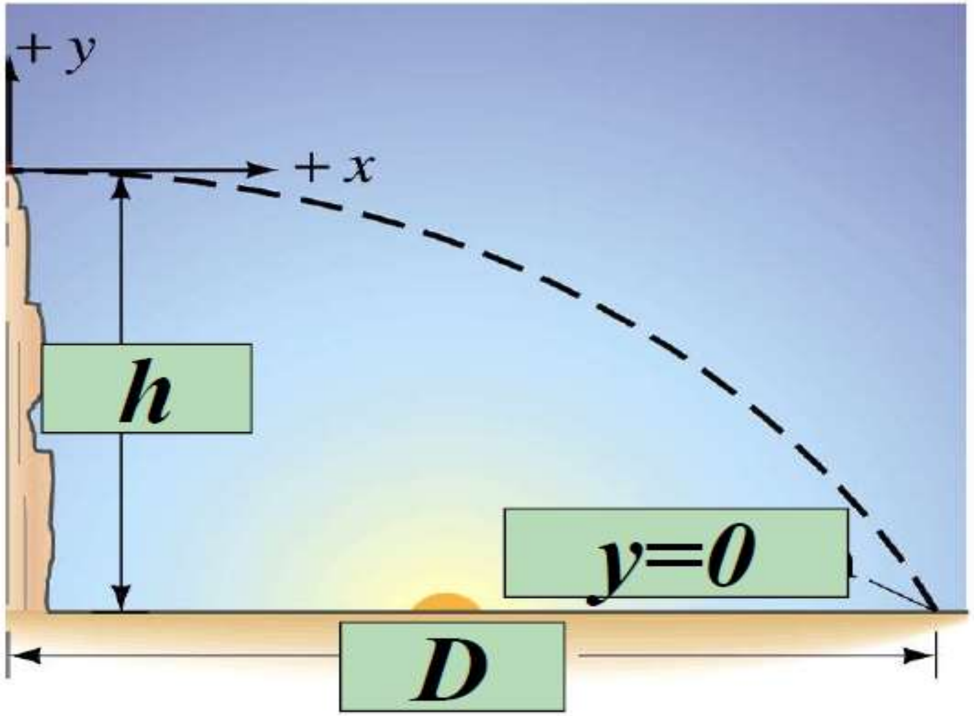
e) What angle maximizes the distance traveled

Assume the ball leaves the foot at ground level and ignore air resistance

Rock and Cliff Problem

A ball is thrown horizontally out off a cliff of a height *h* above the ground. The ball hits the ground a distance *D* from the base of the cliff.

Assuming the ball was moving horizontally at the top and ignoring air friction, what was its initial velocity?



Rescue Plane

You are the pilot of a rescue plane. Your mission is to drop supplies to isolated mountain climbers on a rocky ridge a height *h* below. If your plane is traveling horizontally with a speed of V_O:

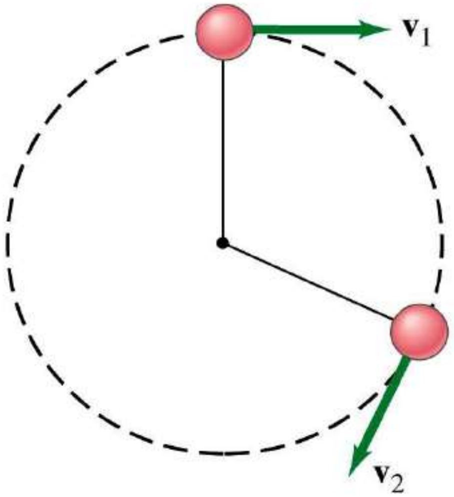
How far in advance of the recipients (horizontal distance) must the goods be dropped?

Uniform Circular Motion

Fancy words for moving in a circle with constant *speed*

We see this around us all the time

- Moon around the earth
- Earth around the sun
- Merry-go-rounds

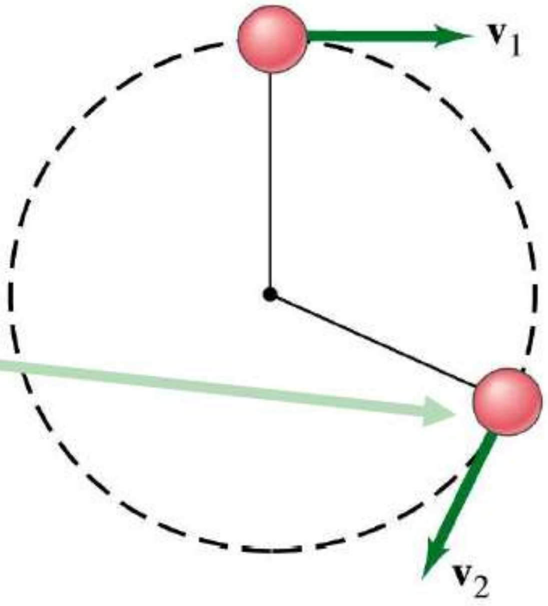


Uniform Circular Motion - Velocity

Velocity vector = |V| tangent to the circle

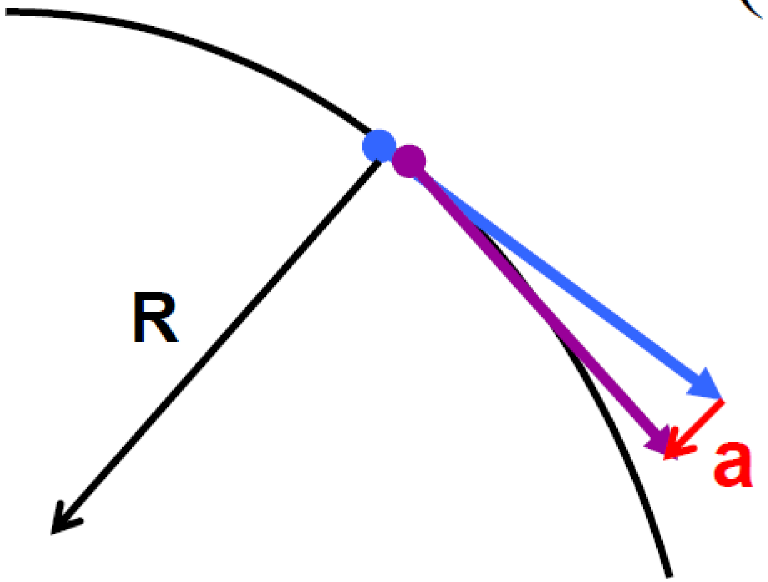
Is this ball accelerating?

- Why?



Centripetal Acceleration

$$\vec{a} = d\vec{v} / dt \approx (\vec{v}_2 - \vec{v}_1) / dt$$



Vector difference V2 - V1 gives the direction of acceleration a

Centripetal Acceleration

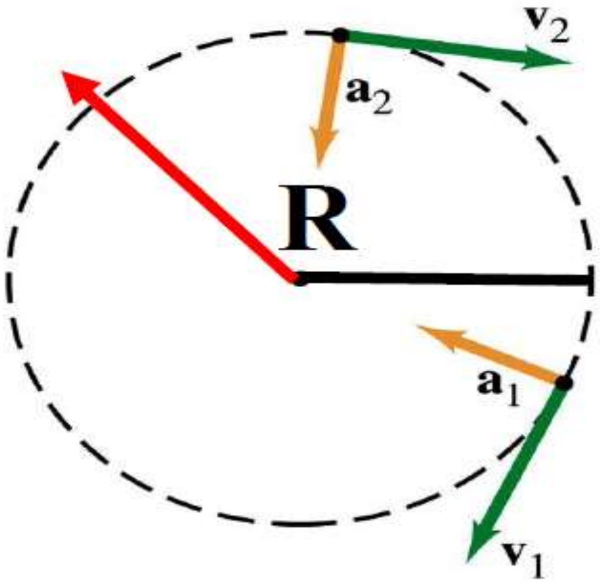
"Center Seeking"

Acceleration vector points *towards the center,* perpendicular to velocity

$$\vec{a} = \frac{v^2}{R}(-\hat{r})$$

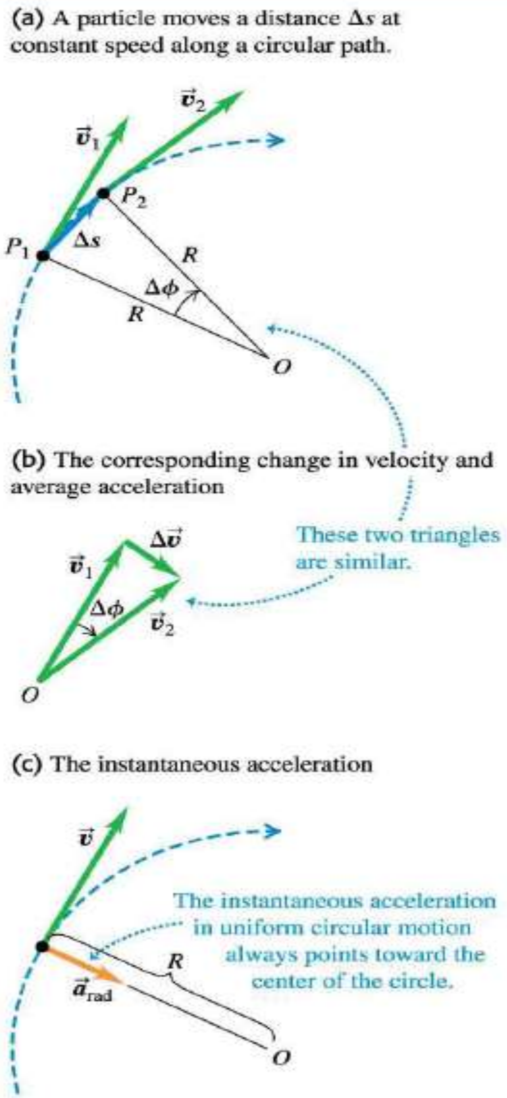
Direction changes, mag same

Unlike projectile motion, where ***a*** has same mag and direction along path



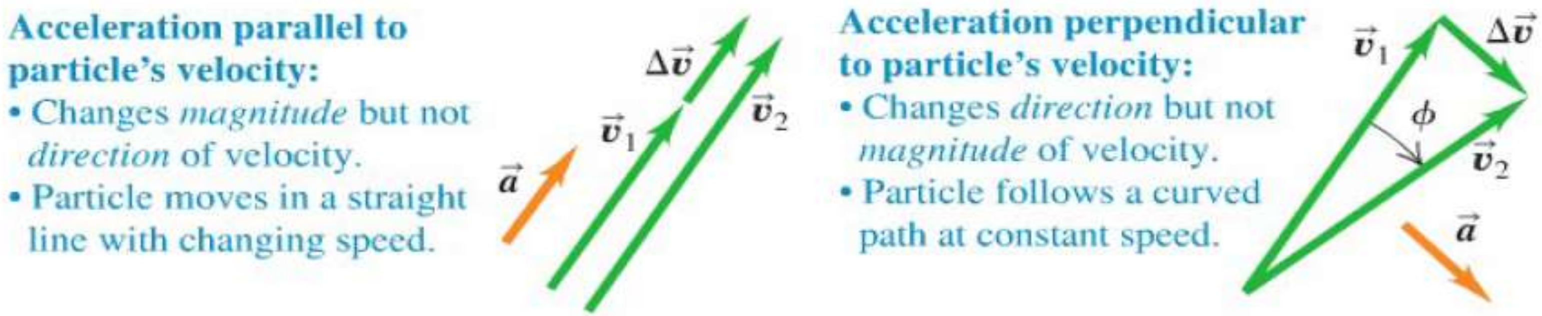
Acceleration for uniform circular motion

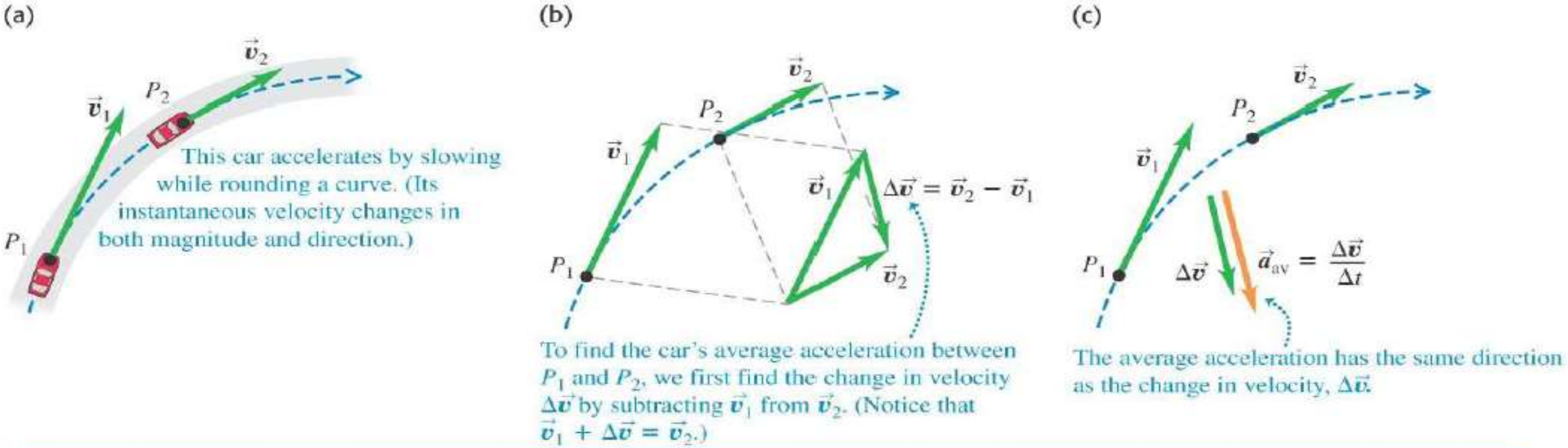
- For uniform circular motion, the instantaneous acceleration always points toward the center of the circle and is called the *centripetal acceleration*.
- The magnitude of the acceleration is $a_{rad} = v^2/R$.
- The *period T* is the time for one revolution, and $a_{rad} = 4\pi^2 R/T^2$.



The acceleration vector: graphical interpretation

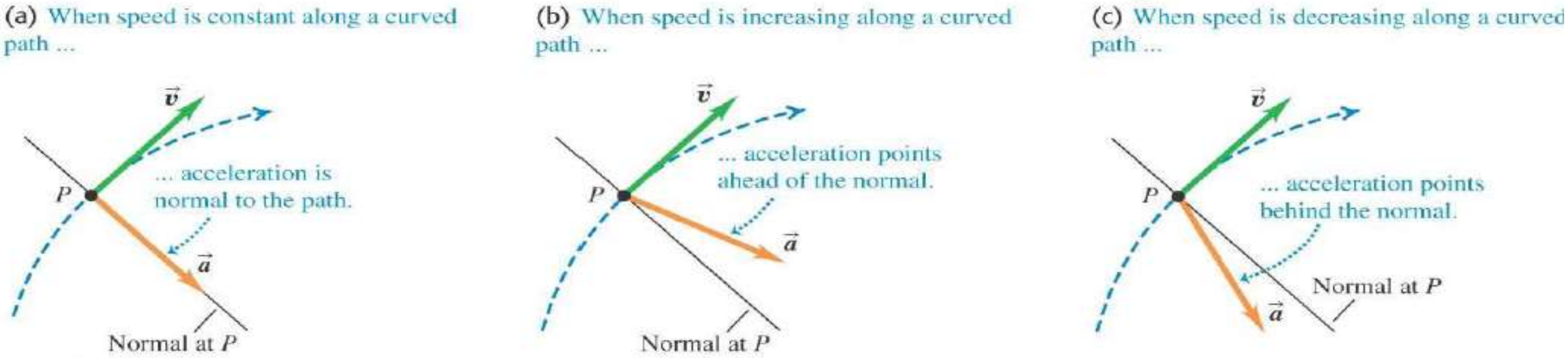
The acceleration vector can result in a change in either the magnitude OR the direction of the velocity.





Different acceleration scenarios

- Notice the acceleration vector change as velocity decreases, remains the same, or increases as one goes around a curve.



Circular Motion: Get the speed!

Speed = distance/time

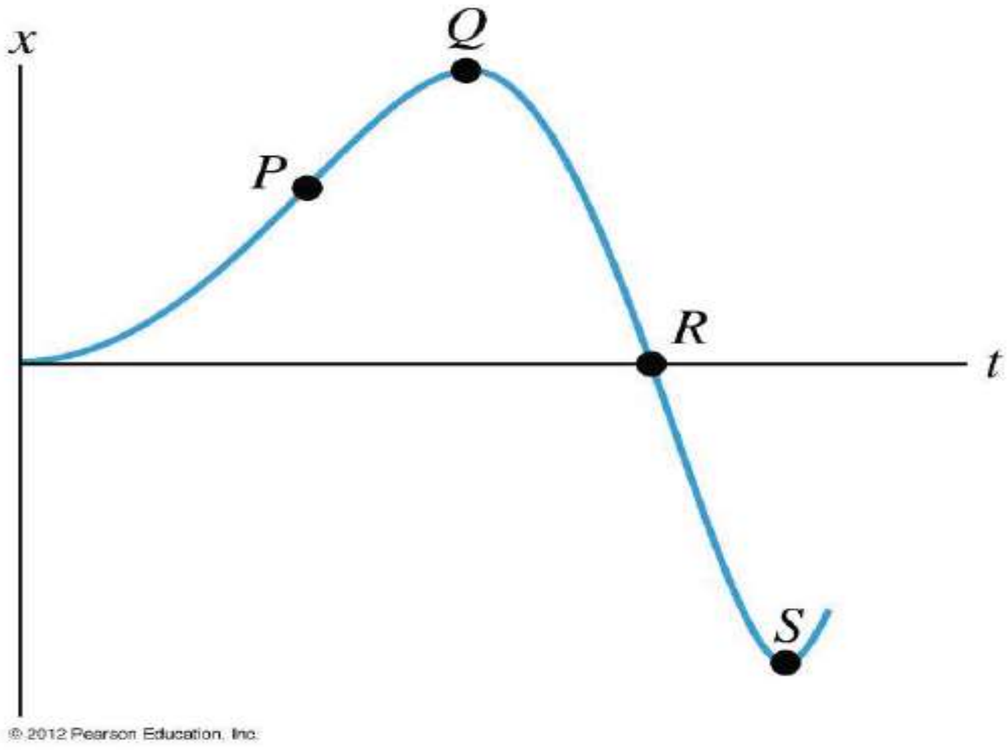
Distance in 1 revolution divided by the time it takes to go around once

Speed = $2\pi r/T$

Note: The time to go around once is known as the Period, or T

$$a = v^2/r = (2\pi r/T)^2/r = 4\pi^2 r/T^2$$

Q2.1

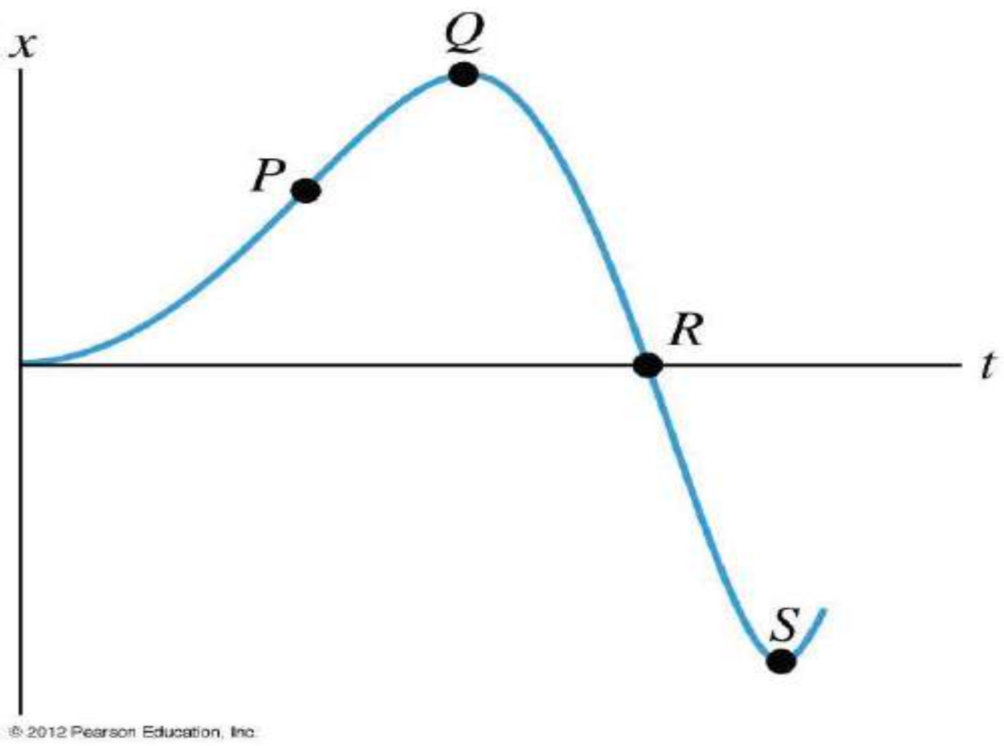


This is the x-t graph of the motion of a particle. Of the four points P, Q, R, and S, the velocity v_x is greatest (most positive) at

A. point P. B. point Q. C. point R. D. point S.

E. not enough information in the graph to decide

Q2.2

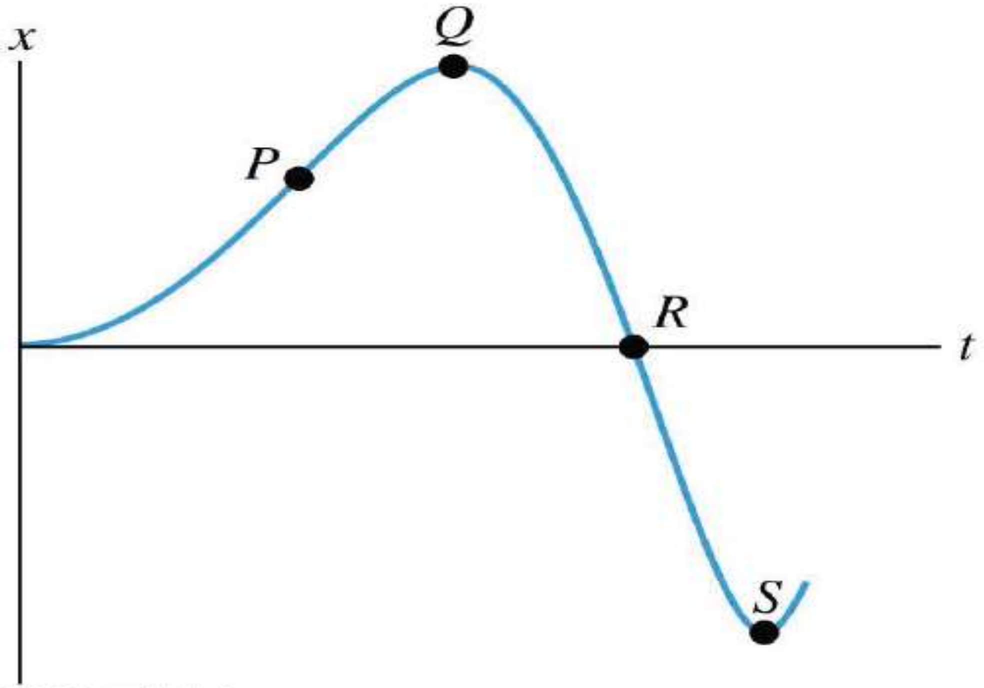


This is the x-t graph of the motion of a particle. Of the four points *P*, *Q*, *R*, and *S*, the speed is greatest at

A. point *P*.   B. point *Q*.   C. point *R*.   D. point *S*.

E. not enough information in the graph to decide

Q2.3



This is the x-t graph of the motion of a particle. Of the four points P, Q, R, and S, the acceleration a_x is greatest (most positive) at

A. point P. B. point Q. C. point R. D. point S.

E. not enough information in the graph to decide

Q2.4

You toss a ball straight upward, in the positive direction. The ball falls freely under the influence of gravity.

At the highest point in the ball's motion,

A. its velocity is zero and its acceleration is zero.

B. its velocity is zero and its acceleration is positive (upward).

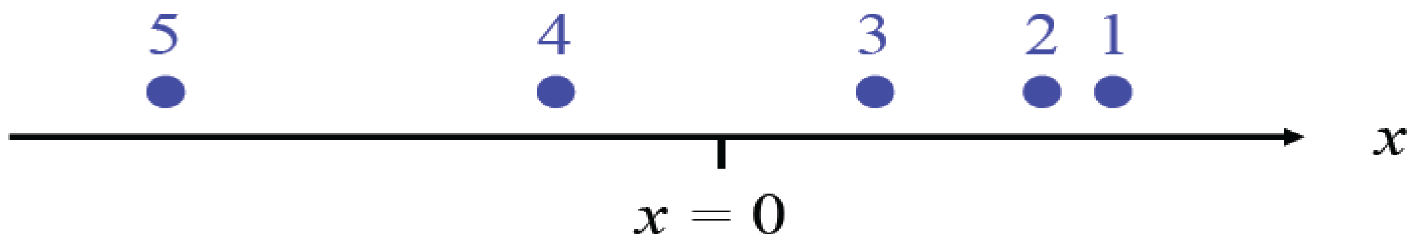
C. its velocity is zero and its acceleration is negative (downward).

D. its velocity is positive (upward) and its acceleration is zero.

E. its velocity is positive (upward) and its acceleration is zero.

Q2.5

This is a motion diagram of an object moving along the x-direction with constant acceleration. The dots 1, 2, 3, … show the position of the object at equal time intervals Δt.



At the time labeled 3, what are the signs of the object's velocity v_x and acceleration a_x?

A. $v_x < 0, a_x = 0$

B. $v_x < 0, a_x > 0$

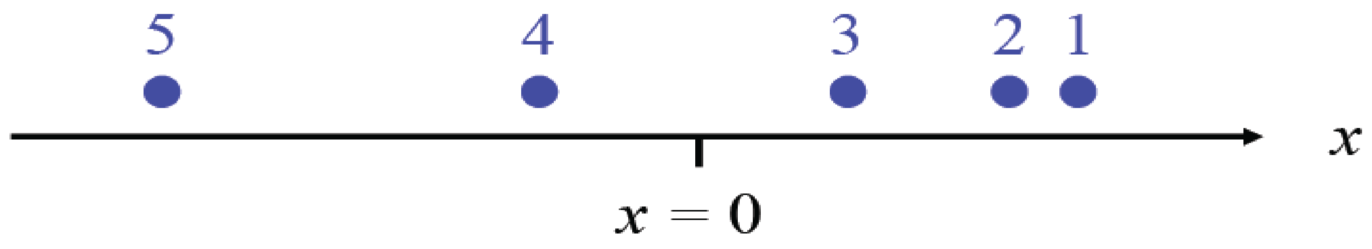
C. $v_x < 0, a_x < 0$

D. $v_x > 0, a_x > 0$

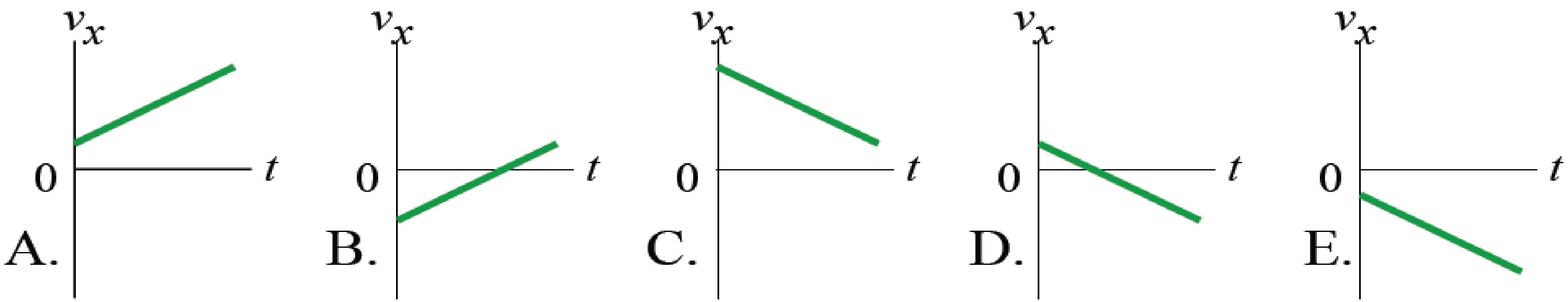
E. $v_x > 0, a_x < 0$

Q2.6

This is a motion diagram of an object moving along the x-direction with constant acceleration. The dots 1, 2, 3, … show the position of the object at equal time intervals Δt.

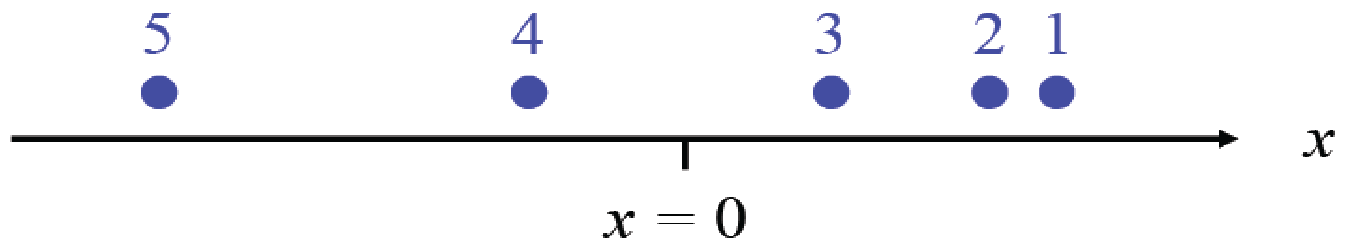


Which of the following v_x-t graphs best matches the motion shown in the motion diagram?

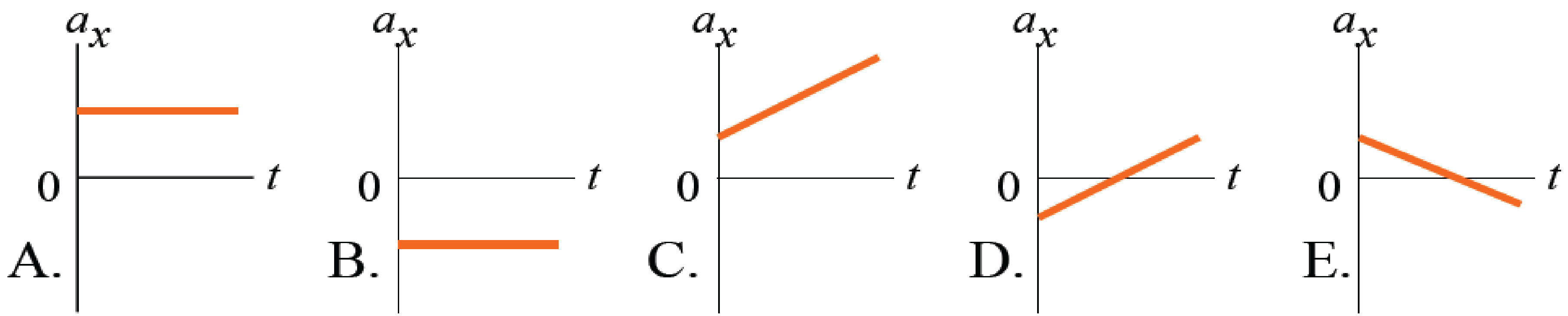


Q2.7

This is a motion diagram of an object moving along the x-direction with constant acceleration. The dots 1, 2, 3, … show the position of the object at equal time intervals Δt.



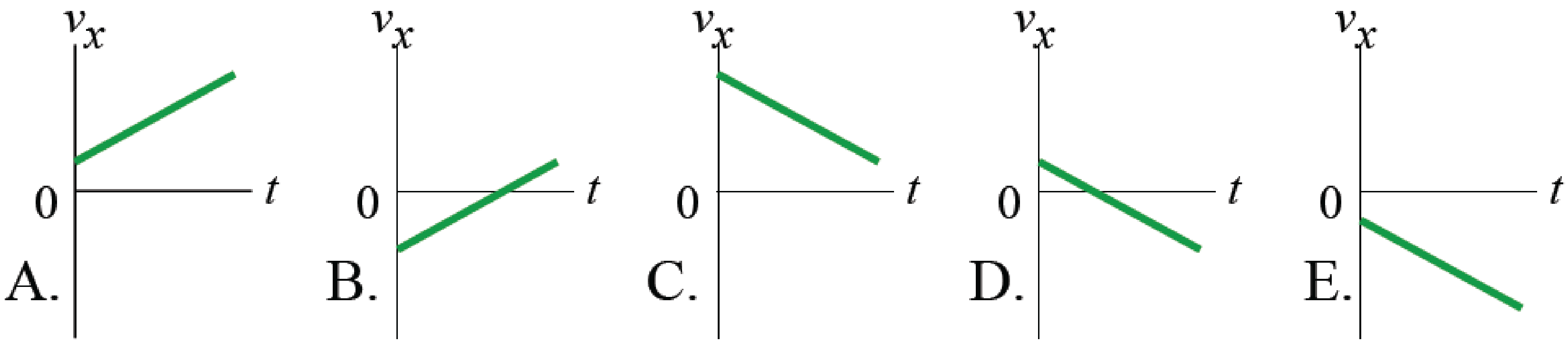
Which of the following a_x–t graphs best matches the motion shown in the motion diagram?

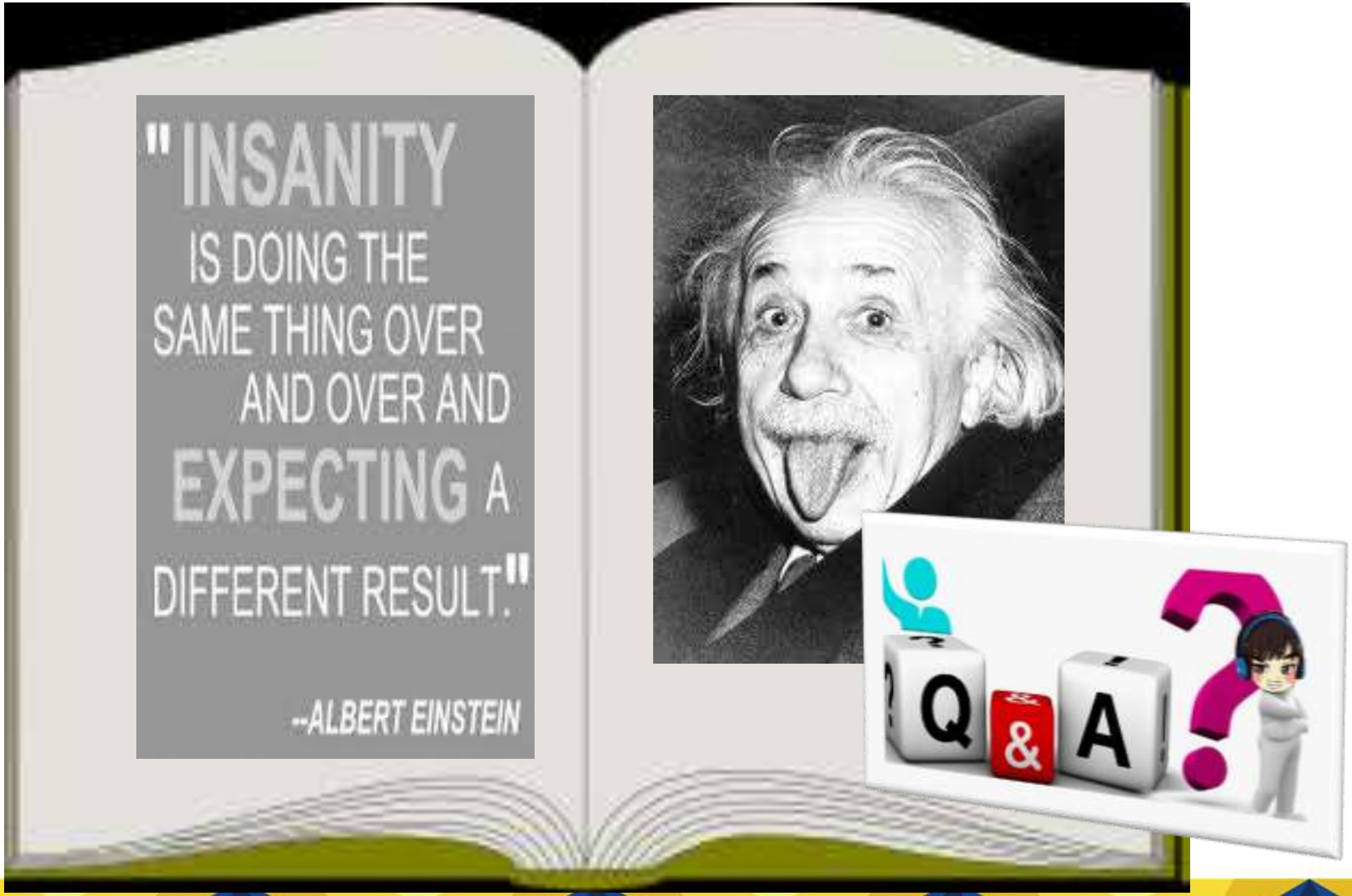


Q2.8

An object moves along the x-axis with constant acceleration. The initial position x_0 is positive, the initial velocity is negative, and the acceleration is positive.

Which of the following v_x-t graphs best describes this motion?




"INSANITY
IS DOING THE
SAME THING OVER
AND OVER AND
EXPECTING A
DIFFERENT RESULT."
--ALBERT EINSTEIN
Q & A