

- Name:
- How many semesters of physics?
- How many semesters of calculus?
- Year at UR (first, sophomore, ...)?

2

-
- Periodic Table of the Elements
- | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------|----------------------|----------------------|----------------------|--------------------------|------------------------|------------------------|-----------------------|----------------------|------------------------|---------------------|------------------------|---------------------|-----------------------|----------------------|-----------------------|----------------------|---------------------|-----------------------|-----------------------|-----------------------|--------------------------|--------------------------|------------------------|------------------------|-----------------------|------------------------|------------------------|------------------------|--------------------------|------------------------|------------------------|-----------------------|-----------------------|-----------------------|-----------------------|--------------------------|------------------------|-----------------------|-----------------------|-----------------------|--------------------|-----------------------|-------------------------|-------------------------|---------------------|-------------------------|----------------------|------------------------|----------------------|---------------------|----------------------|----------------------|---------------------|----------------------|-------------------|
| 1
H
Hydrogen | | | | | | | | | | | | | | | | | 72
Hf
Hafnium | 73
Ta
Tantalum | 74
W
Tungsten | 75
Re
Rhenium | 76
Os
Osmium | 77
Ir
Iridium | 78
Pt
Platinum | 79
Au
Gold | 80
Hg
Mercury | 81
Tl
Thallium | 82
Pb
Lead | 83
Bi
Bismuth | 84
Po
Polonium | 85
At
Astatine | 86
Rn
Radon | | | | | | | | | | | | | | | | | | | | | | | | |
| 2
He
Helium | | | | | | | | | | | | | | | | | 71
Y
Yttrium | 70
Yb
Ytterbium | 69
Tm
Thulium | 68
Er
Erbium | 67
Ho
Holmium | 66
Dy
Dysprosium | 65
Tb
Terbium | 64
Gd
Gadolinium | 63
Eu
Europium | 62
Sm
Samarium | 61
Pm
Promethium | 60
Nd
Neodymium | 59
Pr
Praseodymium | 58
Ce
Cerium | 57
La
Lanthanum | | | | | | | | | | | | | | | | | | | | | | | | |
| 3
Li
Lithium | 4
Be
Beryllium | | | | | | | | | | | | | | | | | 55
Cs
Cesium | 54
Xe
Xenon | 53
I
Iodine | 52
Te
Tellurium | 51
Sb
Antimony | 50
Sn
Tin | 49
In
Indium | 48
Cd
Cadmium | 47
Ag
Silver | 46
Pd
Palladium | 45
Rh
Rhodium | 44
Ru
Ruthenium | 43
Tc
Technetium | 42
Mo
Molybdenum | 41
Nb
Niobium | 40
Zr
Zirconium | 39
Y
Yttrium | 38
Sr
Strontium | 37
Rb
Rubidium | 36
Kr
Krypton | | | | | | | | | | | | | | | | | | |
| 4
Na
Sodium | 5
Mg
Magnesium | | | | | | | | | | | | | | | | | 56
Ba
Barium | 55
La
Lanthanum | 54
Ce
Cerium | 53
Pr
Praseodymium | 52
Nd
Neodymium | 51
Pm
Promethium | 50
Sm
Samarium | 49
Eu
Europium | 48
Gd
Gadolinium | 47
Tb
Terbium | 46
Dy
Dysprosium | 45
Ho
Holmium | 44
Er
Erbium | 43
Tm
Thulium | 42
Yb
Ytterbium | 41
Lu
Lutetium | 39
Zr
Zirconium | 38
Nb
Niobium | 37
Mo
Molybdenum | 36
Tc
Technetium | 35
Ru
Ruthenium | 34
Rh
Rhodium | 33
Pd
Palladium | 32
Ag
Silver | 31
Au
Gold | 30
Hg
Mercury | 29
Cu
Copper | 28
Ni
Nickel | 27
Co
Cobalt | 26
Fe
Iron | 25
Mn
Manganese | 24
Cr
Chromium | 23
V
Vanadium | 22
Ti
Titanium | 21
Sc
Scandium | 20
Ca
Calcium | 19
K
Potassium | 18
Ar
Argon |
| 5
K
Potassium | 6
Ca
Calcium | 7
Sc
Scandium | 8
Ti
Titanium | 9
V
Vanadium | 10
Cr
Chromium | 11
Mn
Manganese | 12
Fe
Iron | 13
Co
Cobalt | 14
Ni
Nickel | 15
Cu
Copper | 16
Zn
Zinc | 17
Ga
Gallium | 18
Ge
Germanium | 19
As
Arsenic | 20
Se
Selenium | 21
Br
Bromine | 22
Kr
Krypton | 23
Rb
Rubidium | 24
Sr
Strontium | 25
Y
Yttrium | 26
Zr
Zirconium | 27
Nb
Niobium | 28
Mo
Molybdenum | 29
Tc
Technetium | 30
Ru
Ruthenium | 31
Rh
Rhodium | 32
Pd
Palladium | 33
Ag
Silver | 34
Cd
Cadmium | 35
In
Indium | 36
Sn
Tin | 37
Sb
Antimony | 38
Te
Tellurium | 39
I
Iodine | 40
Xe
Xenon | | | | | | | | | | | | | | | | | | | | |
| 6
Rb
Rubidium | 7
Sr
Strontium | 8
Y
Yttrium | 9
Zr
Zirconium | 10
Nb
Niobium | 11
Mo
Molybdenum | 12
Tc
Technetium | 13
Ru
Ruthenium | 14
Rh
Rhodium | 15
Pd
Palladium | 16
Ag
Silver | 17
Cd
Cadmium | 18
In
Indium | 19
Sn
Tin | 20
Sb
Antimony | 21
Te
Tellurium | 22
I
Iodine | 23
Xe
Xenon | 24
Cs
Cesium | 25
Ba
Barium | 26
La
Lanthanum | 27
Ce
Cerium | 28
Pr
Praseodymium | 29
Nd
Neodymium | 30
Pm
Promethium | 31
Sm
Samarium | 32
Eu
Europium | 33
Gd
Gadolinium | 34
Tb
Terbium | 35
Dy
Dysprosium | 36
Ho
Holmium | 37
Er
Erbium | 38
Tm
Thulium | 39
Yb
Ytterbium | 40
Lu
Lutetium | | | | | | | | | | | | | | | | | | | | | |
| 7
Cs
Cesium | 8
Ba
Barium | 9
La
Lanthanum | 10
Ce
Cerium | 11
Pr
Praseodymium | 12
Nd
Neodymium | 13
Pm
Promethium | 14
Sm
Samarium | 15
Eu
Europium | 16
Gd
Gadolinium | 17
Tb
Terbium | 18
Dy
Dysprosium | 19
Ho
Holmium | 20
Er
Erbium | 21
Tm
Thulium | 22
Yb
Ytterbium | 23
Lu
Lutetium | 24
Hf
Hafnium | 25
Ta
Tantalum | 26
W
Tungsten | 27
Re
Rhenium | 28
Os
Osmium | 29
Ir
Iridium | 30
Pt
Platinum | 31
Au
Gold | 32
Hg
Mercury | 33
Tl
Thallium | 34
Pb
Lead | 35
Bi
Bismuth | 36
Po
Polonium | 37
At
Astatine | 38
Rn
Radon | 39
Fr
Francium | 40
Ra
Radium | 41
Ac
Actinium | 42
Th
Thorium | 43
Pa
Protactinium | 44
U
Uranium | 45
Np
Neptunium | 46
Pu
Plutonium | 47
Am
Americium | 48
Cm
Curium | 49
Bk
Berkelium | 50
Cf
Californium | 51
Es
Einsteinium | 52
Fm
Fermium | 53
Md
Mendelevium | 54
No
Nobelium | 55
Lr
Lawrencium | | | | | | | |
- Legend:
- Alkali
 - Alkaline Earth
 - Transition Metals
 - Lanthanides
 - Actinides
 - Halogens
 - Noble Gases
 - Metalloids

3

-
- Periodic Table of the Elements

- The periodic chart orders the chemical elements according to their properties.
- It provides clues to the underlying atomic structure.
- The 'fundamental particles' of the periodic chart are the atoms.
- What is an element?
- Webster's Dictionary: The simplest principles of a subject of study.
- What are the fundamental particles of the elements?

Periodic Table of the Elements

H																	He
Li	Be									B	C	N	O	F	Ne		
Na	Mg									Al	Si	P	S	Cl	Ar		
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra		Rf	Sg	Bh	Hs	Mt	Ds	Rg	Cn		Nh	Fl	Mc	Lv	Ts	Og
La		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
Ac		Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		

Alkali Metals

Alkaline Earth Metals

Transition Metals

Metalloids

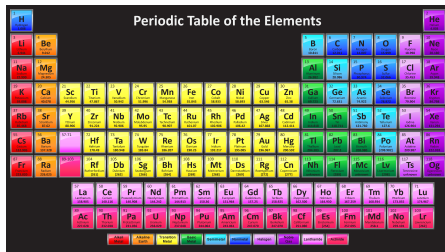
Nonmetals

Noble Gases

Lanthanides

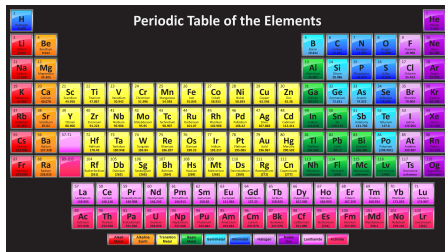
Actinides

- The periodic chart orders the chemical elements according to their properties.
- It provides clues to the underlying atomic structure.
- The 'fundamental particles' of the periodic chart are the atoms.
- What is an element?
- Webster's Dictionary: The simplest principles of a subject of study.
- What are the fundamental particles of the elements?
- Protons, neutrons, and electrons.



A color-coded periodic table of elements. The title "Periodic Table of the Elements" is centered at the top. The table is organized into rows and columns, with elements color-coded by groups: alkali metals (blue), alkaline earth metals (orange), transition metals (yellow), metalloids (green), nonmetals (purple), and noble gases (pink). The lanthanide and actinide series are shown at the bottom, separated from the main body of the table.

- The periodic chart orders the chemical elements according to their properties.
- It provides clues to the underlying atomic structure.
- The 'fundamental particles' of the periodic chart are the atoms.
- What is an element?
- Webster's Dictionary: The simplest principles of a subject of study.
- What are the fundamental particles of the elements?
- Protons, neutrons, and electrons.



What is inside protons and neutrons?

- The Universe is made of quarks and leptons and the force carriers.

BOSONS			force carriers
Unified Electroweak spin = 1			spin = 0, 1, 2, ...
Name	Mass GeV/c ²	Electric charge	
γ photon	0	0	
W^-	80.39	-1	
W^+ W bosons	80.39	+1	
Z^0 Z boson	91.188	0	

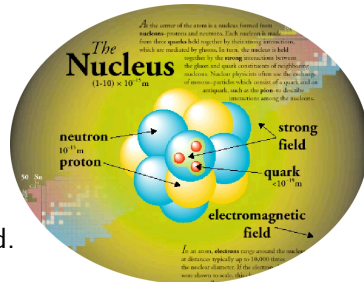
Strong (color) spin = 1		
Name	Mass GeV/c ²	Electric charge
g gluon	0	0

FERMIONS			matter constituents
			spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2		
Flavor	Mass GeV/c ²	Electric charge
ν_L lightest neutrino*	$(0-0.13) \times 10^{-9}$	0
e electron	0.000511	-1
ν_M middle neutrino*	$(0.009-0.13) \times 10^{-9}$	0
μ muon	0.106	-1
ν_H heaviest neutrino*	$(0.04-0.14) \times 10^{-9}$	0
τ tau	1.777	-1

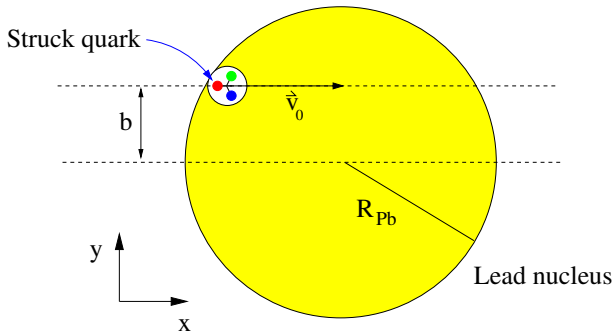
Quarks spin = 1/2		
Flavor	Approx. Mass GeV/c ²	Electric charge
u up	0.002	2/3
d down	0.005	-1/3
c charm	1.3	2/3
s strange	0.1	-1/3
t top	173	2/3
b bottom	4.2	-1/3

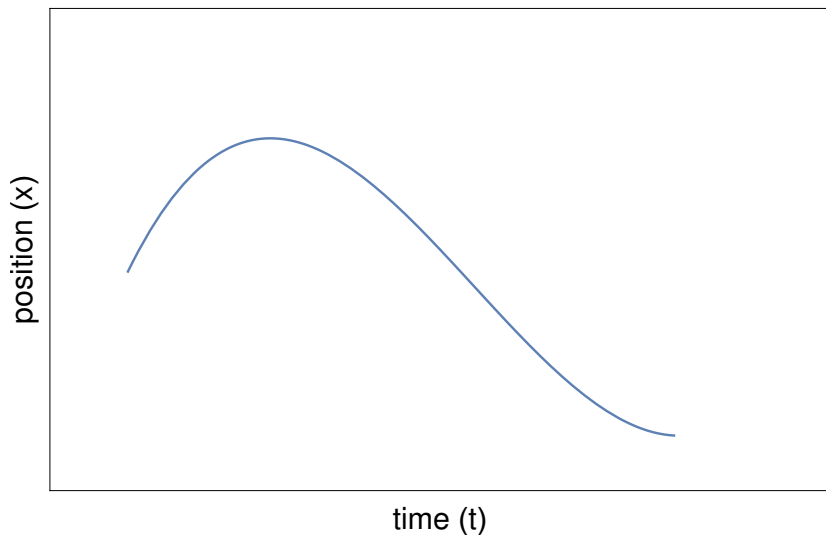
- The atomic nucleus is made of protons and neutrons bound by the strong or color force.
- The quarks are confined inside the protons and neutrons.
- Protons and neutrons are NOT confined.

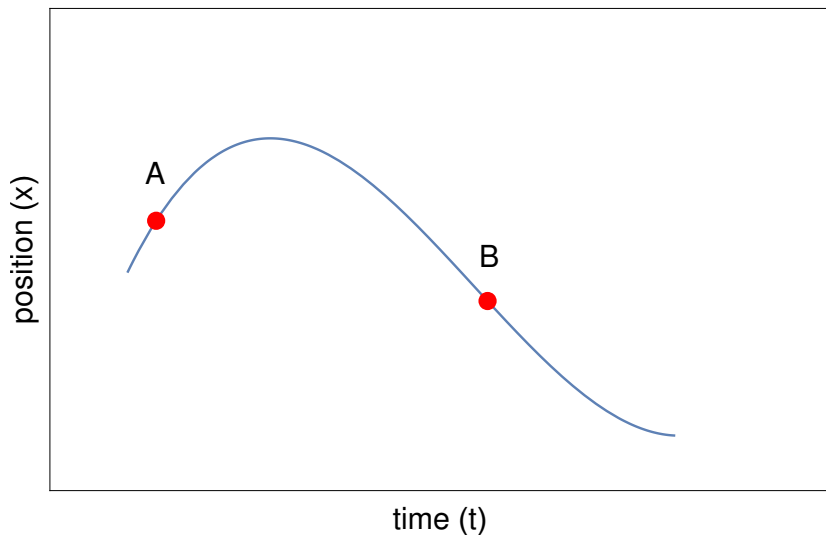


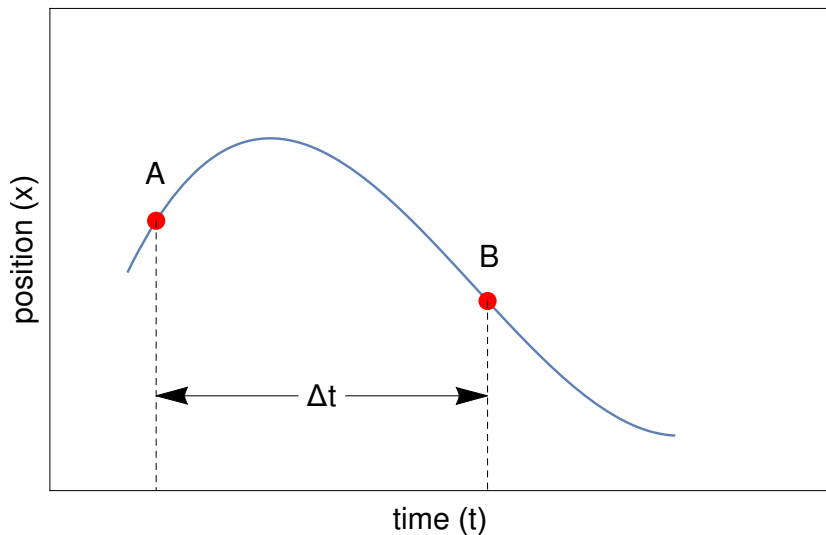
An electron strikes the quark bound inside a nucleon that is a constituent of a lead nucleus in the configuration shown in the figure. The quark is near the surface of the nucleus. The collision gives the quark an initial velocity \vec{v}_0 and an acceleration \vec{a} as it moves through the nuclear medium. See below for numbers. **Does the quark make it out of the nucleus?**

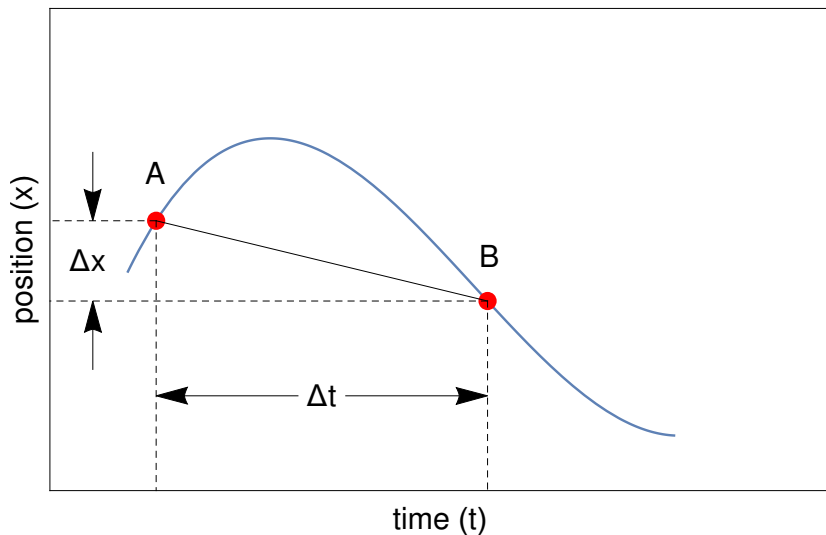
$$\begin{aligned}\vec{v}_0 &= 3 \times 10^8 \text{ m/s } \hat{i} \\ \vec{a} &= -4 \times 10^{30} \text{ m/s}^2 \hat{i} \\ b &= 3.0 \times 10^{-15} \text{ m} \\ R_{Pb} &= 7.1 \times 10^{-15} \text{ m}\end{aligned}$$

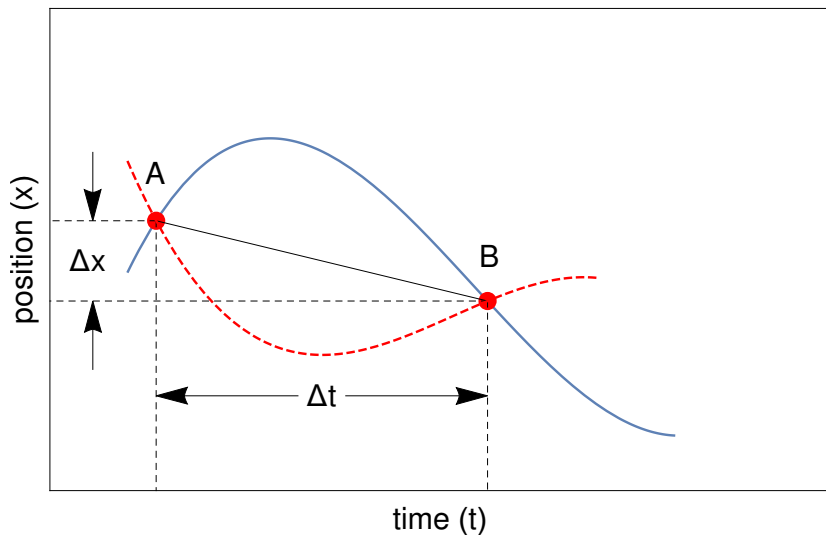


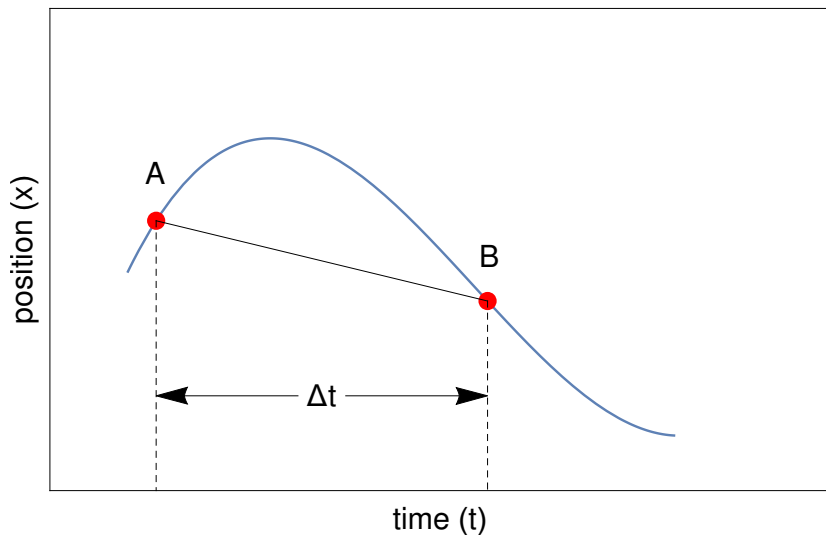


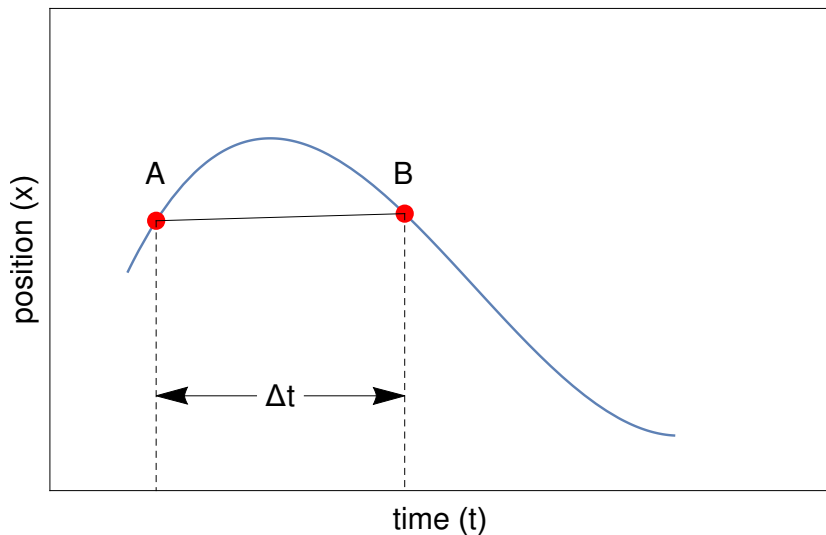


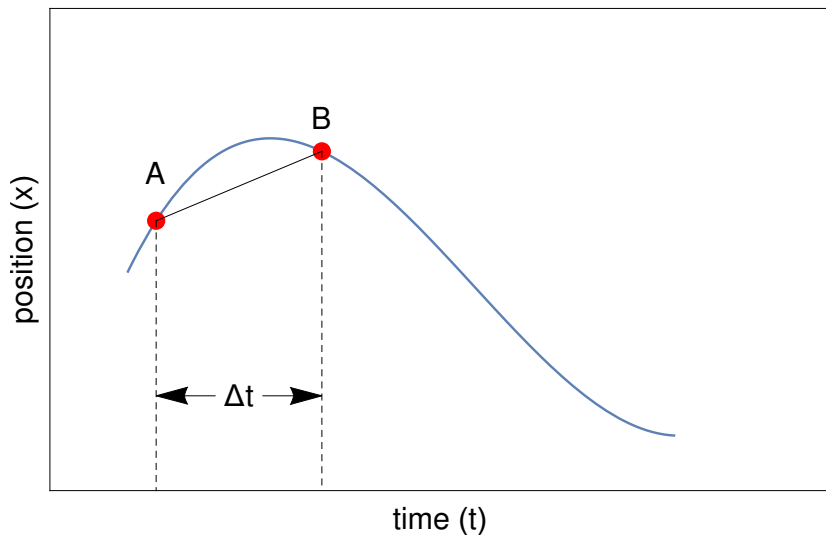


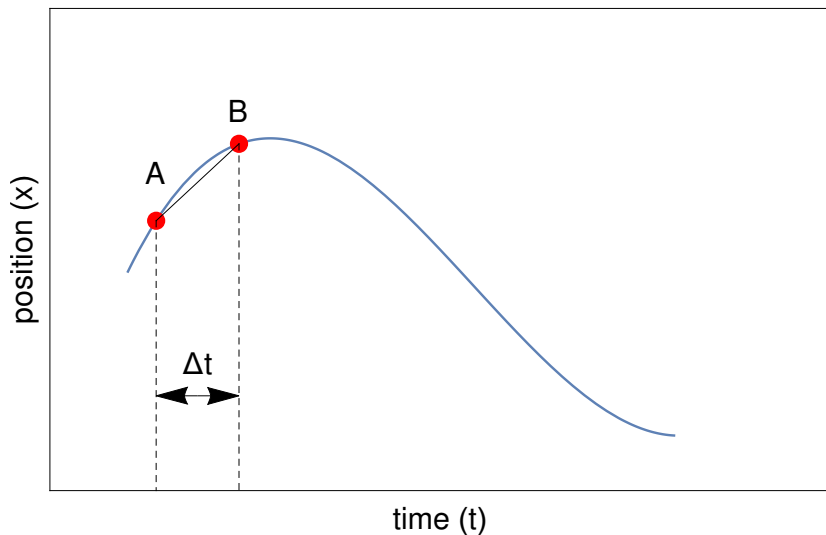


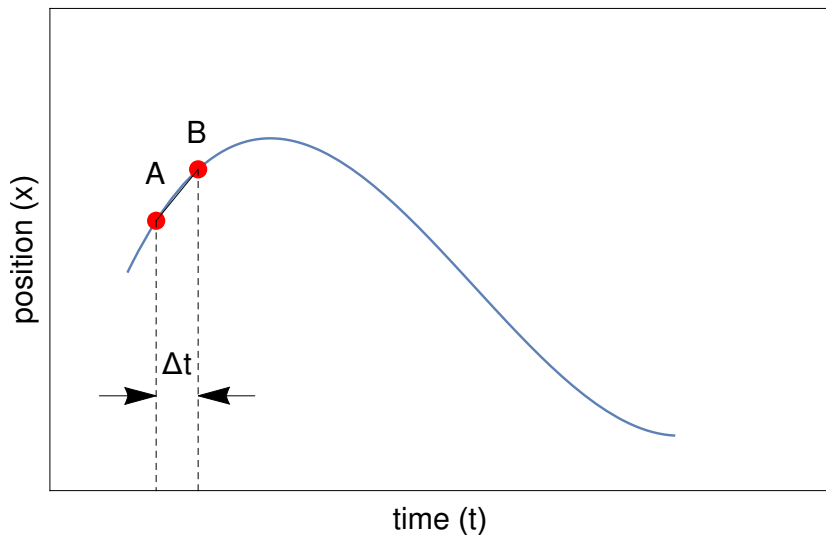


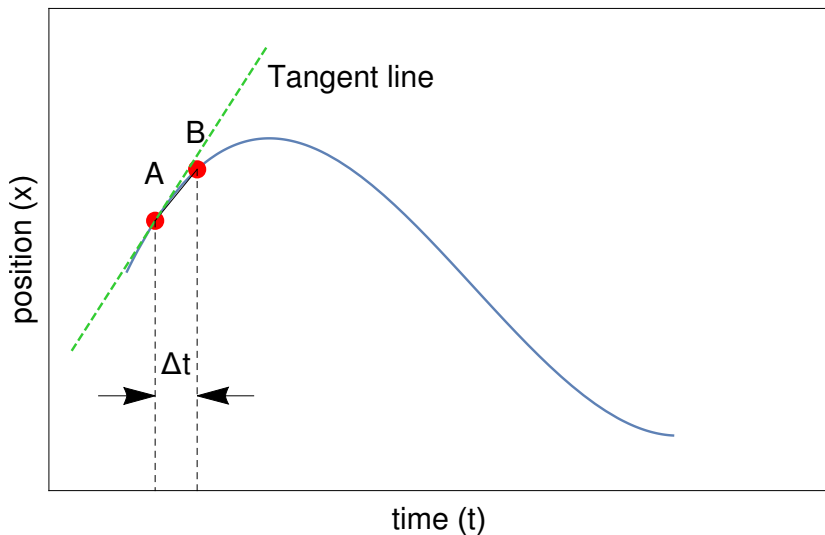


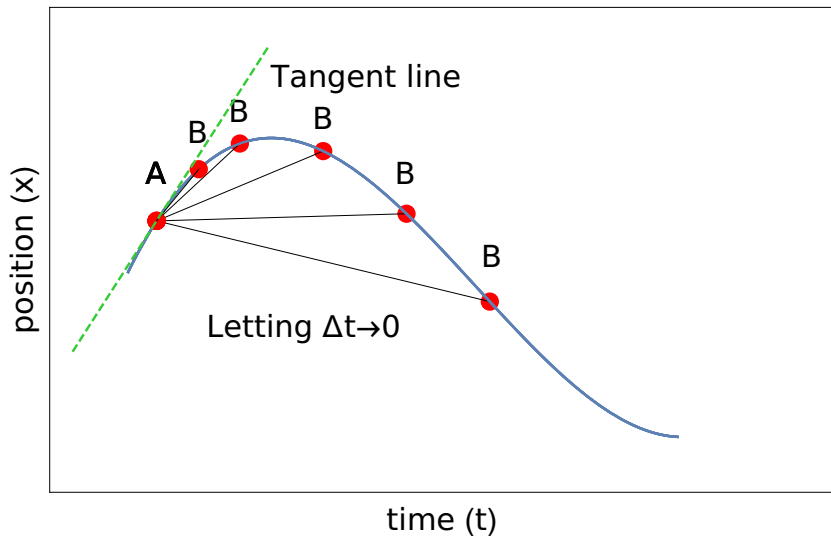












An elevator in the world's tallest building, the Burj Khalifa in Dubai, United Arab Emirates, is moving and its vertical position is described by the following equation

$$x(t) = A + Bt + Ct^2$$

where $A = 5.0 \text{ m}$, $B = 2.1 \text{ m/s}$, and $C = -4.9 \text{ m/s}^2$. What is the instantaneous velocity at any time t ? What is the average velocity between two times $t_0 = 0.0 \text{ s}$ and $t_1 = 1.0 \text{ s}$?





The starship Enterprise has lost power and is plunging straight into the heart of a black hole. Its velocity as a function of time is described by

$$v(t) = F + Gt$$

where $F = 2.0 \times 10^7 \text{ m/s}$ and $G = 9.0 \times 10^{10} \text{ m/s}^2$.

What is the instantaneous acceleration?

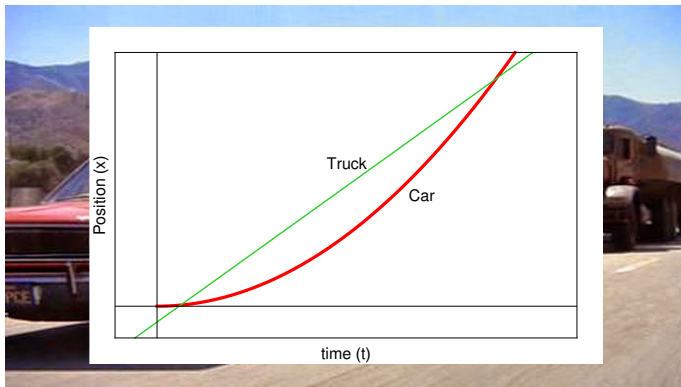
Do the velocity and acceleration versus time plots make sense?



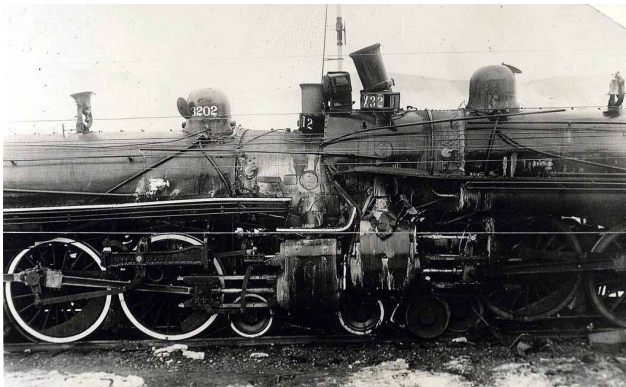
At the instant a traffic light turns green, a 'car' starts with a constant acceleration $a = 2.2 \text{ m/s}^2$. At the same instant a truck is 5.0 m behind the car and traveling with a constant speed $v_t = 9.5 \text{ m/s}$. How far does the car travel before overtaking the truck? What do the position versus time plots look like for the car and the truck?



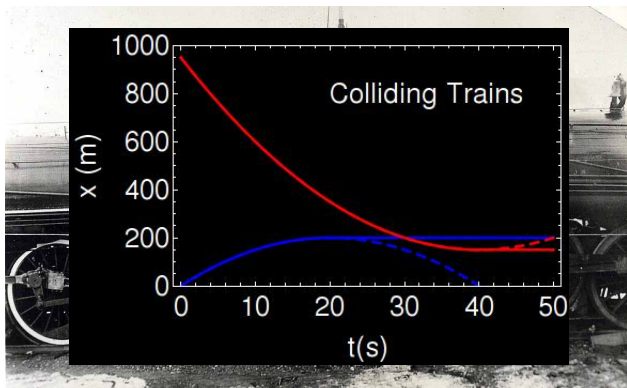
At the instant a traffic light turns green, a 'car' starts with a constant acceleration $a = 2.2 \text{ m/s}^2$. At the same instant a truck is 5.0 m behind the car and traveling with a constant speed $v_t = 9.5 \text{ m/s}$. How far does the car travel before overtaking the truck? What do the position versus time plots look like for the car and the truck?



Two trains, one traveling at 20 m/s and the other at 40 m/s , are headed toward one another along a straight, level track. When they are 950 m apart, each engineer sees the other's train and instantly applies the brakes. The slow-moving train stops. The brakes decelerate each train at a rate of 1.0 m/s^2 . Is there a collision? If so, how long after the brakes are applied?



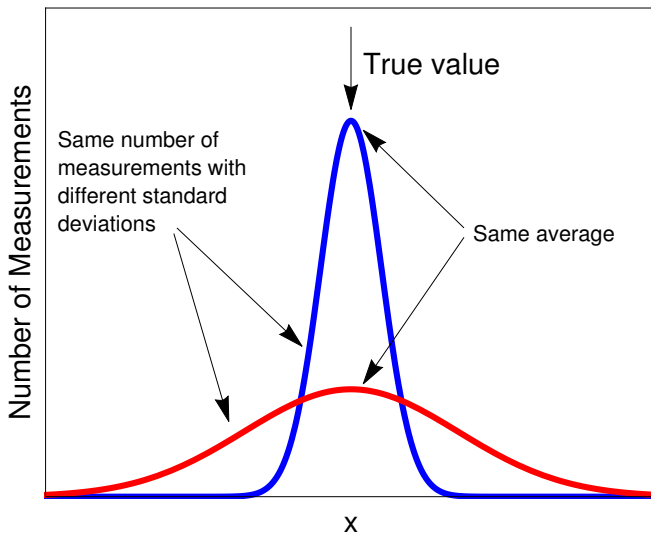
Two trains, one traveling at 20 m/s and the other at 40 m/s , are headed toward one another along a straight, level track. When they are 950 m apart, each engineer sees the other's train and instantly applies the brakes. The slow-moving train stops. The brakes decelerate each train at a rate of 1.0 m/s^2 . Is there a collision? If so, how long after the brakes are applied?



A window washer named Chris Sagger is reported to have fallen (assume starting from rest) 67 meters from a building where he was working, landed on a car, and lived. Suppose the roof of the car was compressed 1.45 m. Ignoring air resistance what is his speed just before hitting the car? Treating his acceleration as constant, how long did it take him to come to a stop after he made contact with the box? What was his acceleration?



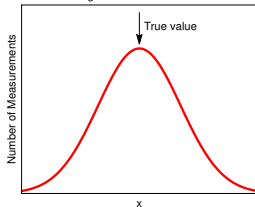
Average and Standard Deviation





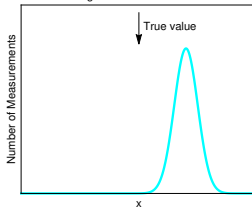
Not precise.

Average and Standard Deviation



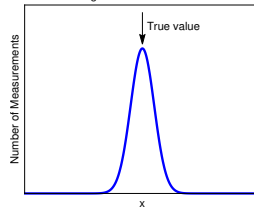
Precise, but not accurate.

Average and Standard Deviation

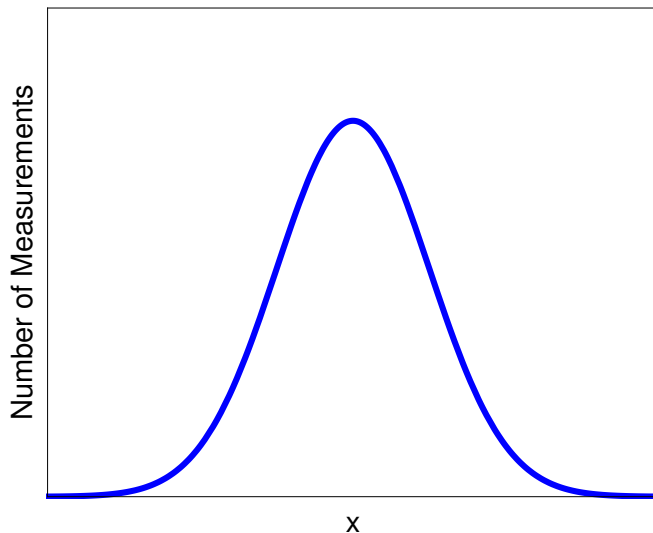


Precise and accurate.

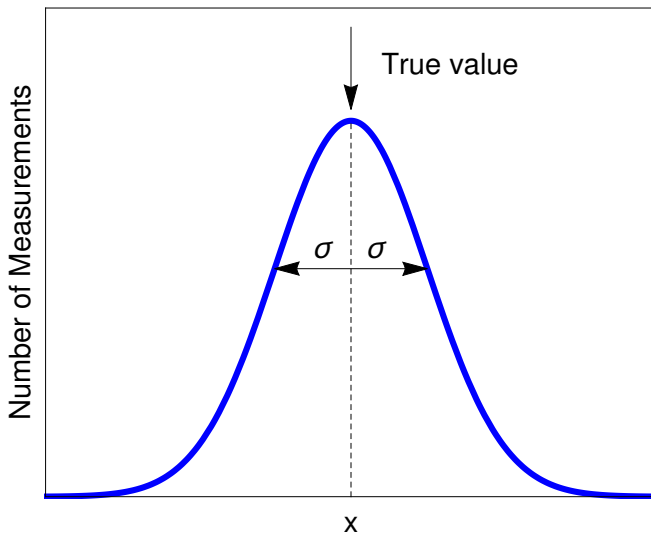
Average and Standard Deviation



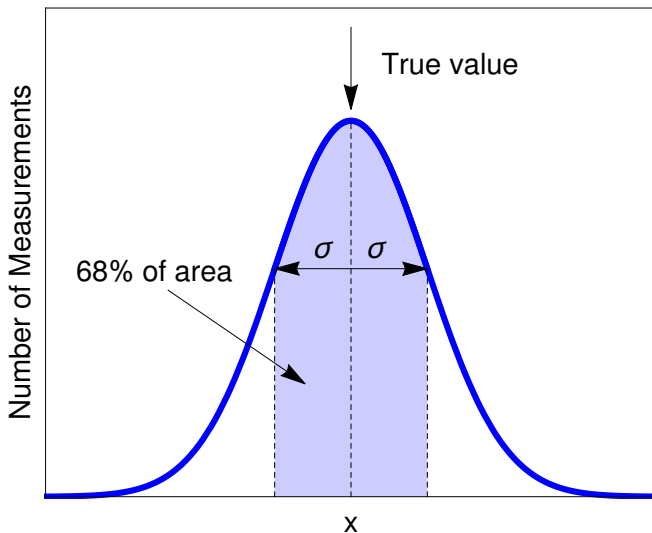
Average and Standard Deviation



Average and Standard Deviation



Average and Standard Deviation



Does the quark escape?

34

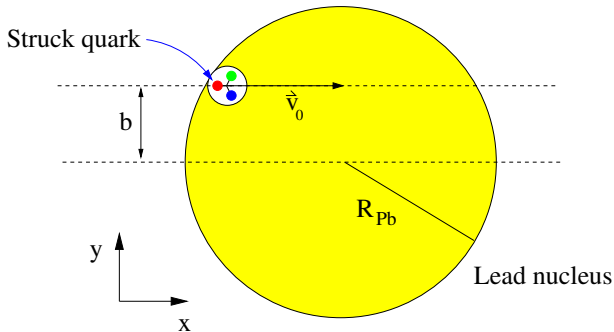
An electron strikes the quark bound inside a proton that is a constituent of a lead nucleus in the configuration shown in the figure. The quark is near the surface of the nucleus. The collision gives the quark an initial velocity \vec{v}_0 and an acceleration \vec{a} as it moves through the nuclear medium. See below for numbers. **Does the quark make it out of the nucleus?**

$$v_o = 3 \times 10^8 \text{ m/s}$$

$$|a| = 4 \times 10^{30} \text{ m/s}^2$$

$$b = 3.0 \times 10^{-15} \text{ m}$$

$$R_{Pb} = 7.1 \times 10^{-15} \text{ m}$$



An electron strikes the quark bound inside a proton that is a constituent of a lead nucleus in the configuration shown in the figure. The quark is near the surface of the nucleus. The collision gives the quark an initial velocity \vec{v}_0 and an acceleration \vec{a} as it moves through the nuclear medium. See below for numbers. **Does the quark make it out of the nucleus?**

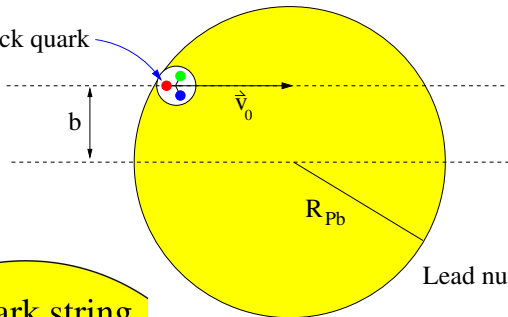
$$v_o = 3 \times 10^8 \text{ m/s}$$

$$|a| = 4 \times 10^{30} \text{ m/s}^2$$

$$b = 3.0 \times 10^{-15} \text{ m}$$

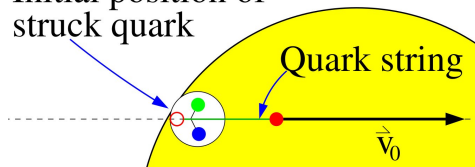
$$R_{Pb} = 7.1 \times 10^{-15} \text{ m}$$

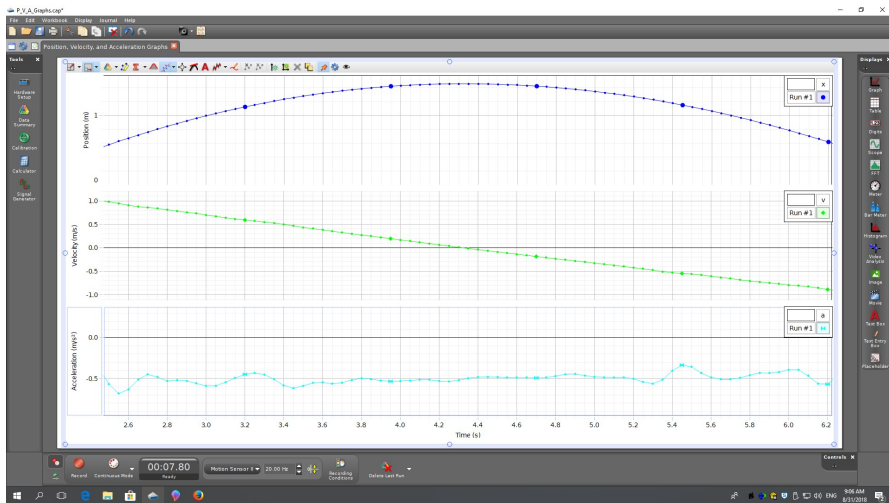
Struck quark



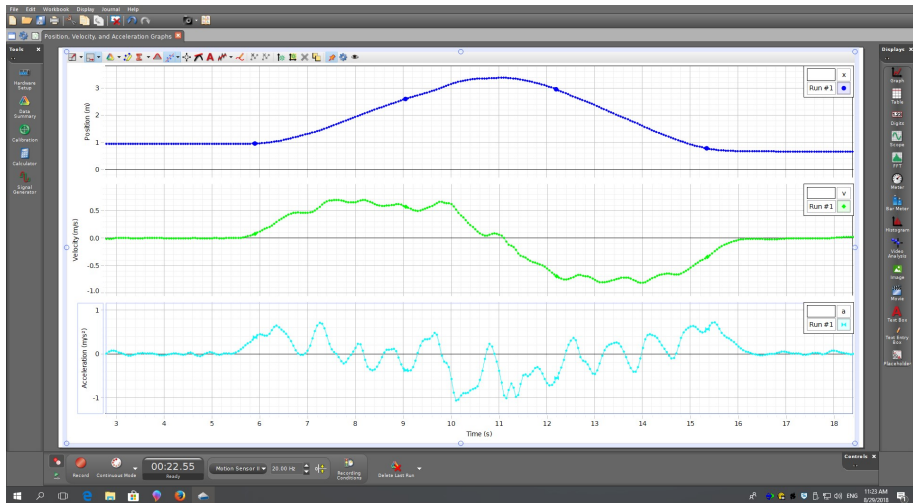
Initial position of struck quark

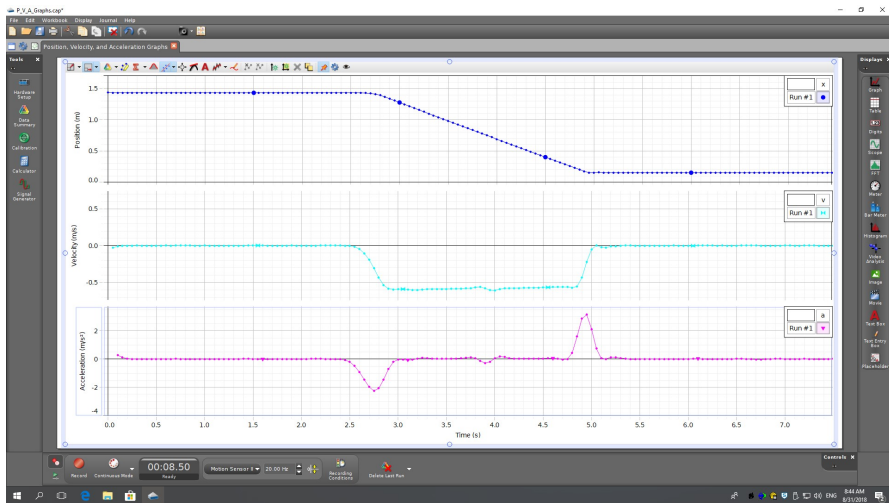
Quark string

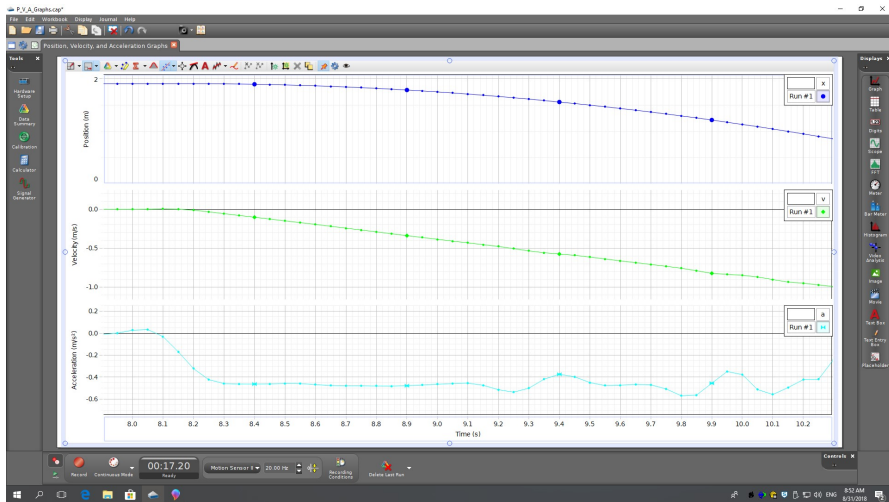


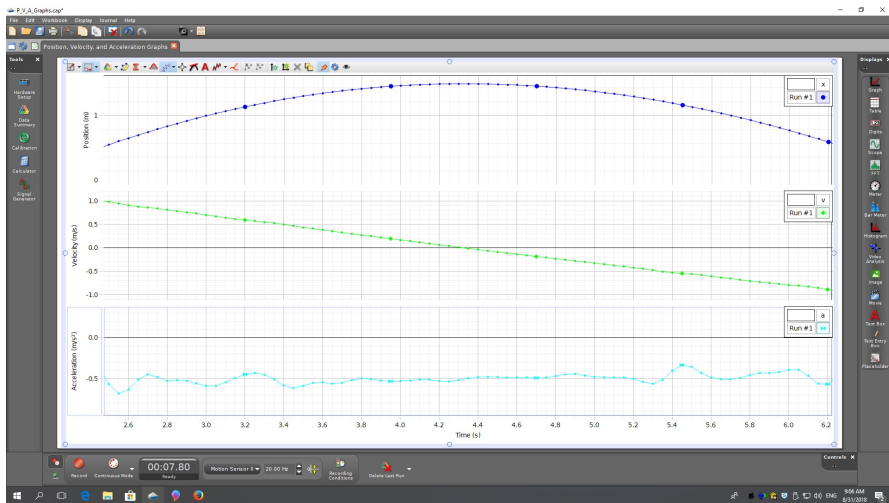


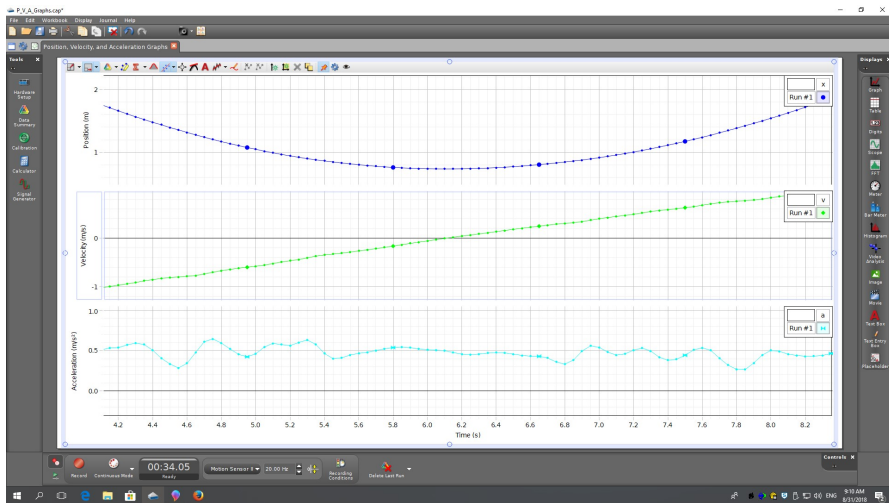


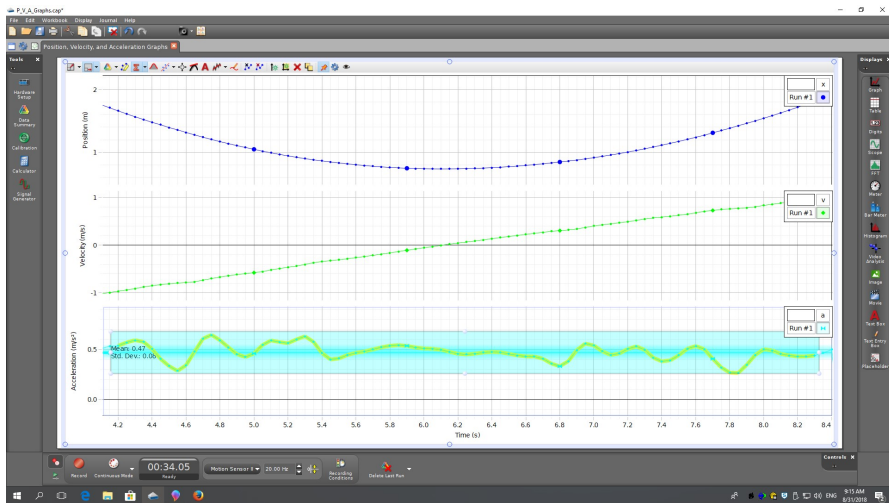












Does the quark escape?

44

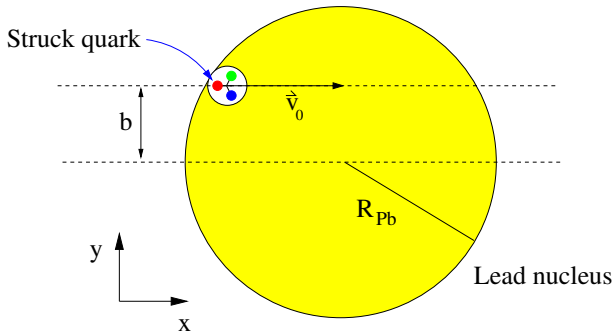
An electron strikes the quark bound inside a proton that is a constituent of a lead nucleus in the configuration shown in the figure. The quark is near the surface of the nucleus. The collision gives the quark an initial velocity \vec{v}_0 and an acceleration \vec{a} as it moves through the nuclear medium. See below for numbers. **Does the quark make it out of the nucleus?**

$$v_o = 3 \times 10^8 \text{ m/s}$$

$$|a| = 4 \times 10^{30} \text{ m/s}^2$$

$$b = 3.0 \times 10^{-15} \text{ m}$$

$$R_{Pb} = 7.1 \times 10^{-15} \text{ m}$$



An electron strikes the quark bound inside a proton that is a constituent of a lead nucleus in the configuration shown in the figure. The quark is near the surface of the nucleus. The collision gives the quark an initial velocity \vec{v}_0 and an acceleration \vec{a} as it moves through the nuclear medium. See below for numbers. **Does the quark make it out of the nucleus?**

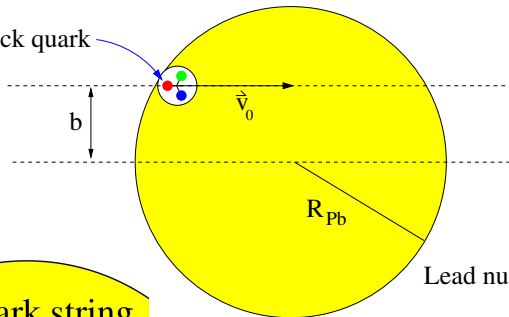
$$v_o = 3 \times 10^8 \text{ m/s}$$

$$|a| = 4 \times 10^{30} \text{ m/s}^2$$

$$b = 3.0 \times 10^{-15} \text{ m}$$

$$R_{Pb} = 7.1 \times 10^{-15} \text{ m}$$

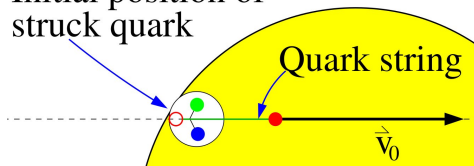
Struck quark



Lead nucleus

Initial position of struck quark

Quark string



Does the quark escape?

46

An electron strikes the quark bound inside a proton that is a constituent of a lead nucleus in the configuration shown in the figure. The quark is near the surface of the nucleus. The collision gives the quark an initial velocity \vec{v}_0 and an acceleration \vec{a} as it moves through the nuclear medium. See below for numbers. **Does the quark make it out of the nucleus?**

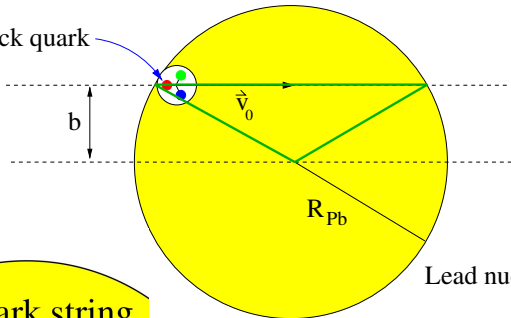
$$v_o = 3 \times 10^8 \text{ m/s}$$

$$|a| = 4 \times 10^{30} \text{ m/s}^2$$

$$b = 3.0 \times 10^{-15} \text{ m}$$

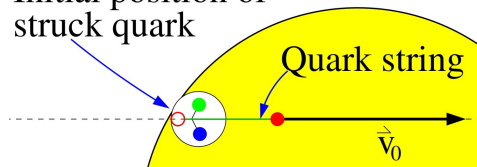
$$R_{Pb} = 7.1 \times 10^{-15} \text{ m}$$

Struck quark



Initial position of struck quark

Quark string



Does the quark escape?

47

An electron strikes the quark bound inside a proton that is a constituent of a lead nucleus in the configuration shown in the figure. The quark is near the surface of the nucleus. The collision gives the quark an initial velocity \vec{v}_0 and an acceleration \vec{a} as it moves through the nuclear medium. See below for numbers. **Does the quark make it out of the nucleus?**

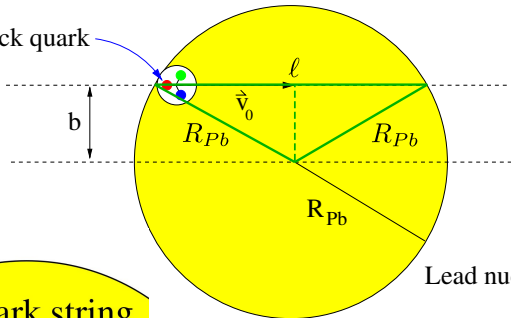
$$v_o = 3 \times 10^8 \text{ m/s}$$

$$|a| = 4 \times 10^{30} \text{ m/s}^2$$

$$b = 3.0 \times 10^{-15} \text{ m}$$

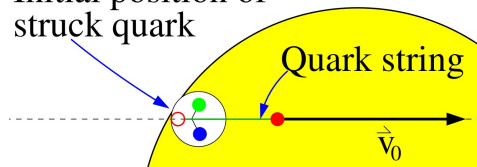
$$R_{Pb} = 7.1 \times 10^{-15} \text{ m}$$

Struck quark



Initial position of struck quark

Quark string



Does the quark escape?

48

An electron strikes the quark bound inside a proton that is a constituent of a lead nucleus in the configuration shown in the figure. The quark is near the surface of the nucleus. The collision gives the quark an initial velocity \vec{v}_0 and an acceleration \vec{a} as it moves through the nuclear medium. See below for numbers. **Does the quark make it out of the nucleus?**

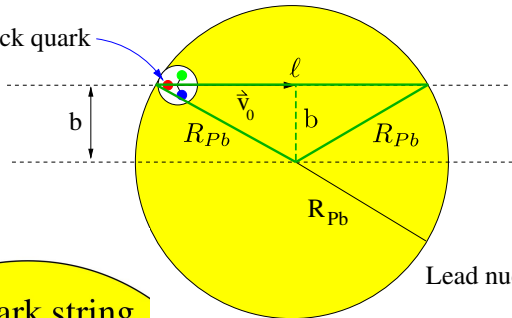
$$v_o = 3 \times 10^8 \text{ m/s}$$

$$|a| = 4 \times 10^{30} \text{ m/s}^2$$

$$b = 3.0 \times 10^{-15} \text{ m}$$

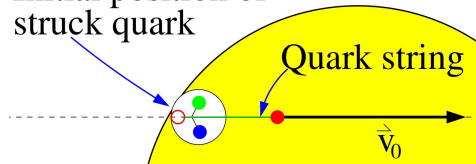
$$R_{Pb} = 7.1 \times 10^{-15} \text{ m}$$

Struck quark



Initial position of struck quark

Quark string



Does the quark escape?

49

An electron strikes the quark bound inside a proton that is a constituent of a lead nucleus in the configuration shown in the figure. The quark is near the surface of the nucleus. The collision gives the quark an initial velocity \vec{v}_0 and an acceleration \vec{a} as it moves through the nuclear medium. See below for numbers. **Does the quark make it out of the nucleus?**

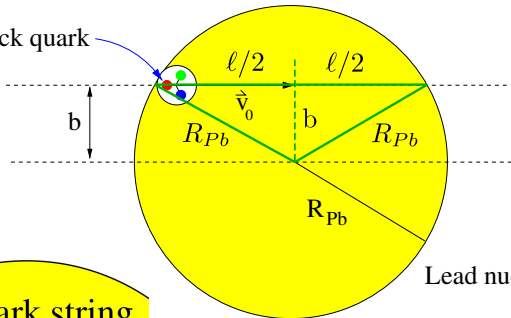
$$v_o = 3 \times 10^8 \text{ m/s}$$

$$|a| = 4 \times 10^{30} \text{ m/s}^2$$

$$b = 3.0 \times 10^{-15} \text{ m}$$

$$R_{Pb} = 7.1 \times 10^{-15} \text{ m}$$

Struck quark



Initial position of struck quark

Quark string

