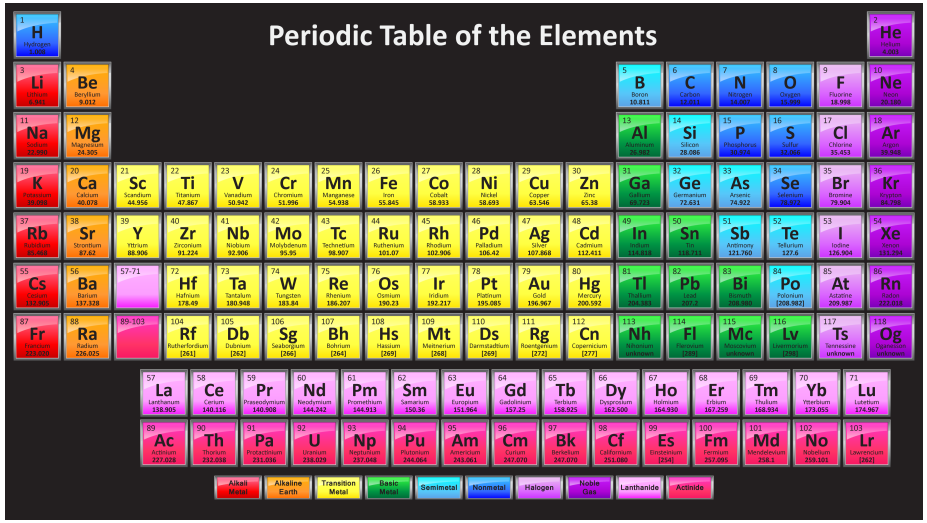
Personal Information 1

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

The Frontiers of Matter (in 1932) 2

- 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?



The Frontiers of Matter (in 1932) 3

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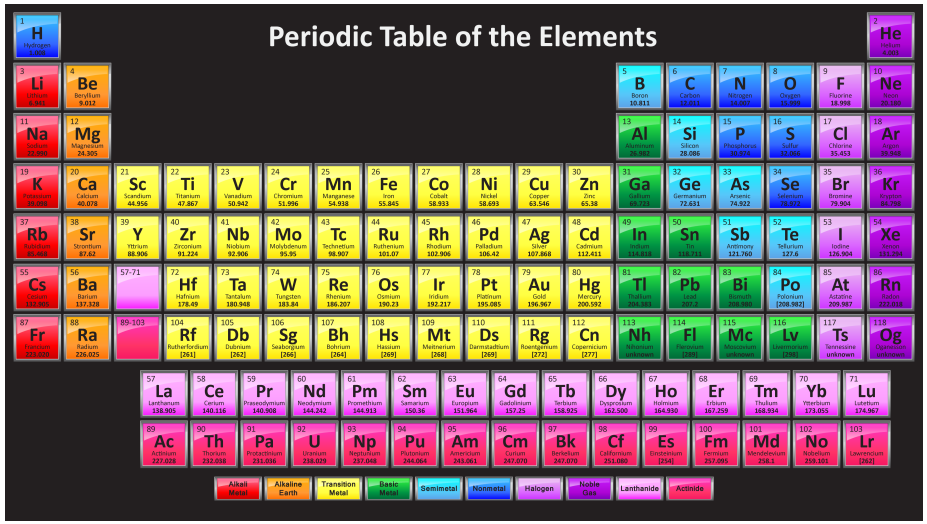

- What is an element?
- Webster's Dictionary: The simplest principles of a subject of study.

The Frontiers of Matter (in 1932) 4

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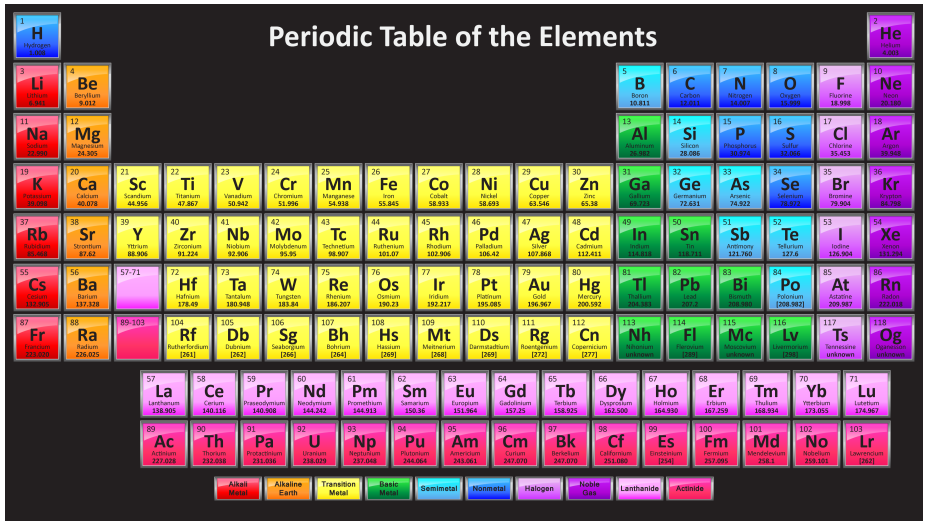

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- What are the fundamental particles of the elements?

The Frontiers of Matter (in 1932) 5

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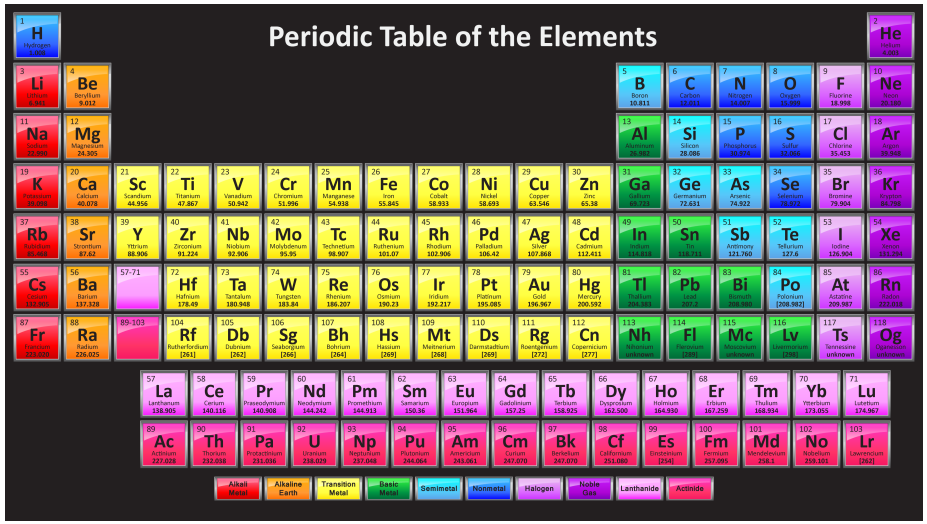

- What is an element?
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- What are the fundamental particles of the elements?
- Protons and neutrons.

The Frontiers of Matter (in 1932) 6

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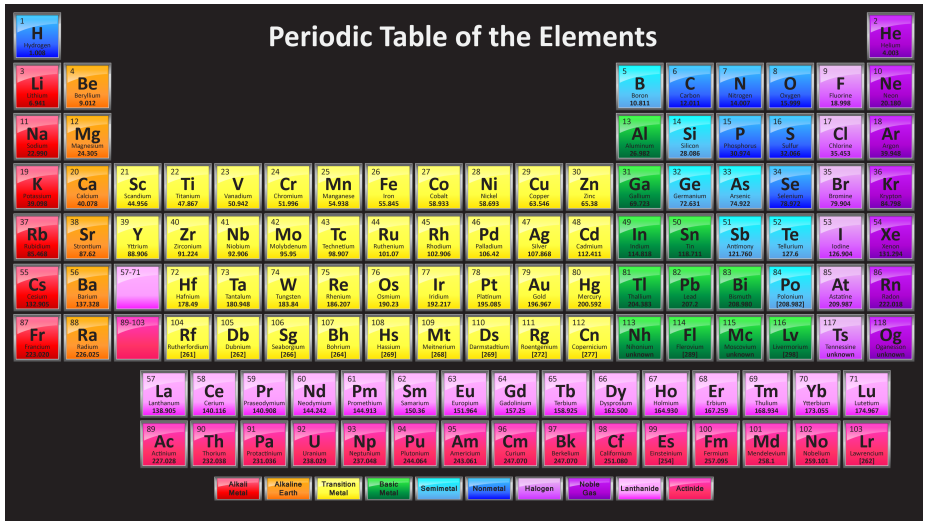

- What is an element?
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- What are the fundamental particles of the elements?
- Protons and neutrons.

What is inside protons and neutrons?

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

BOSONS force carriers spin = 0, 1, 2, ...

Unified Electroweak spin = 1

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, ...

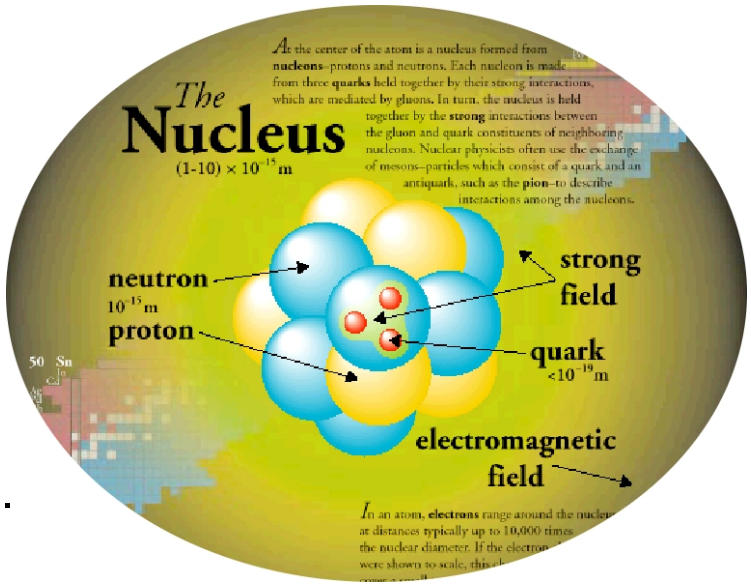
Leptons spin =1/2

Flavor	Mass GeV/c^2	Electric charge
ν_L lightest neutrino*	$(0–0.13)\times10^{-9}$	0
e electron	0.000511	–1
ν_M middle neutrino*	$(0.009–0.13)\times10^{-9}$	0
μ muon	0.106	–1
ν_H heaviest neutrino*	$(0.04–0.14)\times10^{-9}$	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

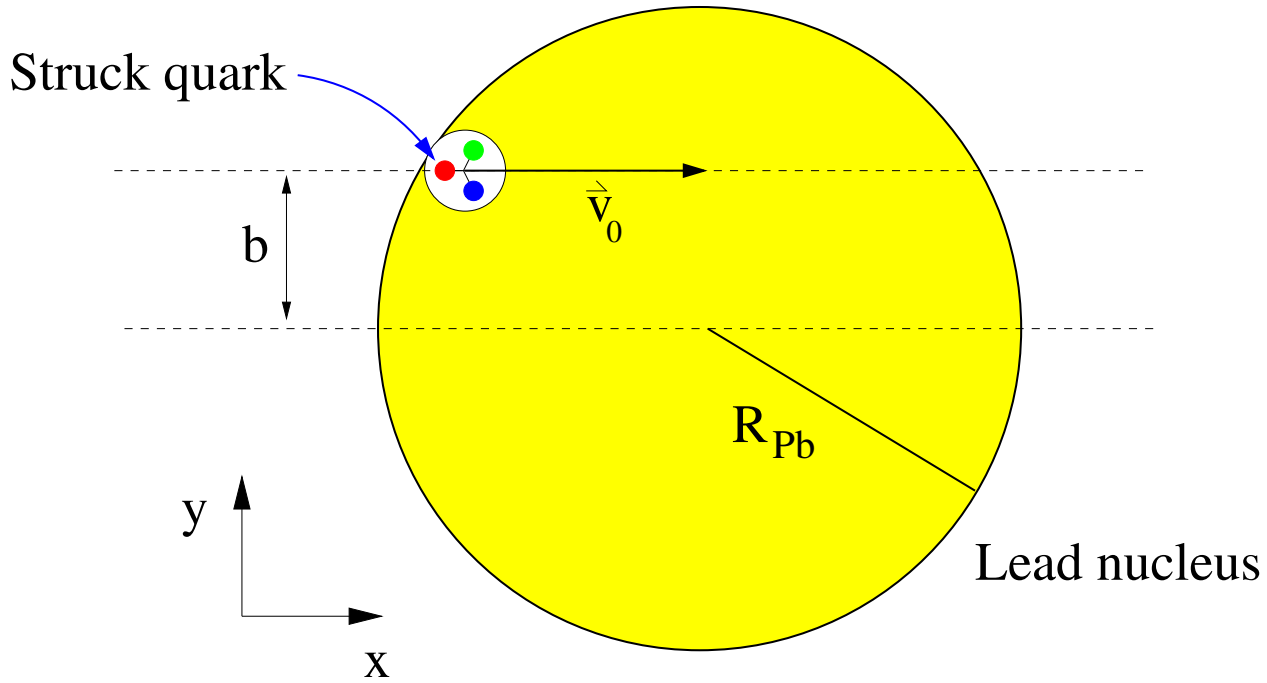
- The atomic nucleus is made of protons and neutrons bound by the strong or color force.
- The quarks are confined inside the protons and neutrons.
- Protons and neutrons are NOT confined.



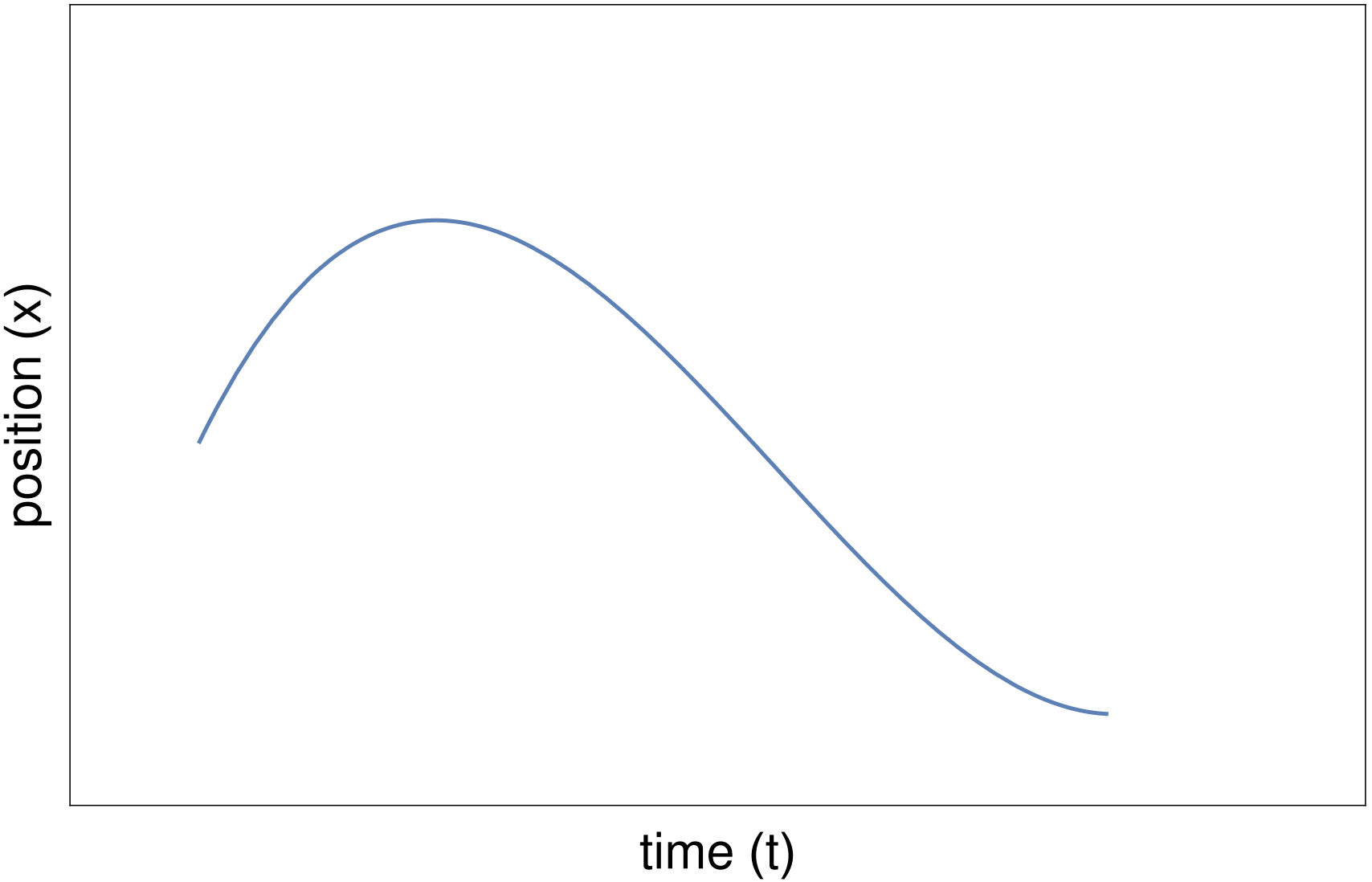
Does the quark escape? 8

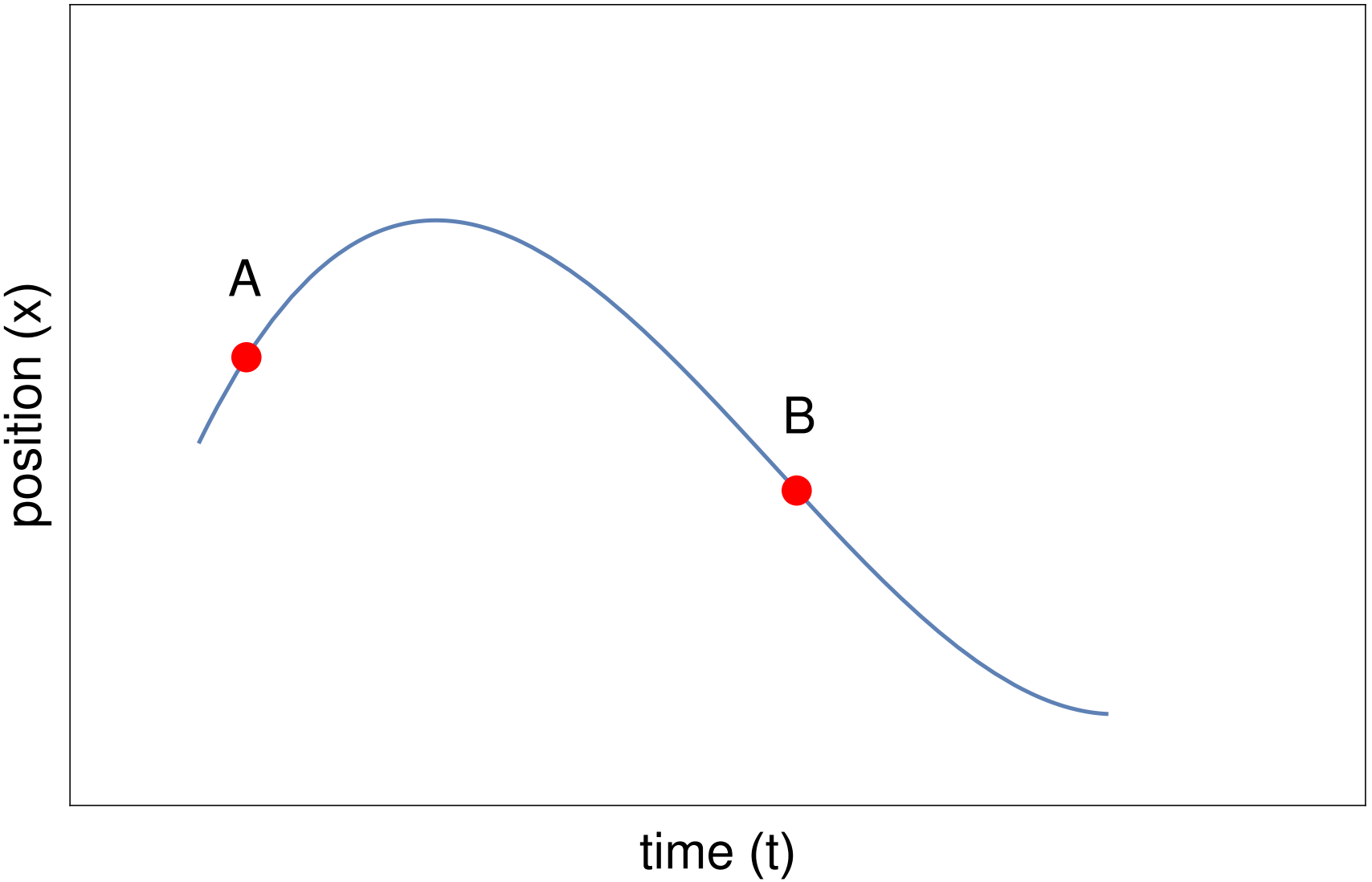
An electron strikes the quark bound inside a nucleon that is a constituent of a lead nucleus in the configuration shown in the figure. The quark is near the surface of the nucleus. The collision gives the quark an initial velocity $\vec{v}_o$ and an acceleration $\vec{a}$ as it moves through the nuclear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

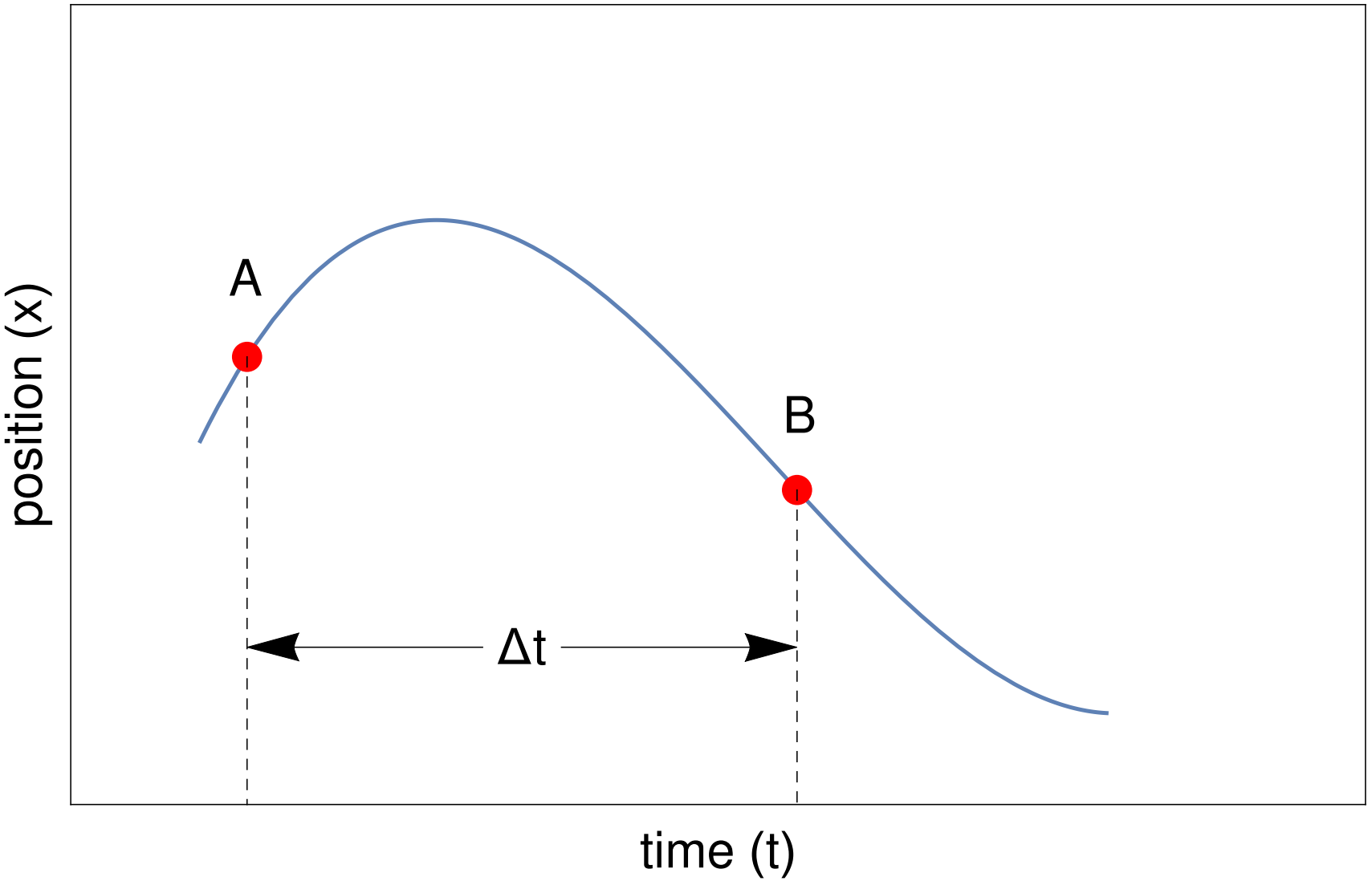
$\vec{v}_o = 3 \times 10^8 \ m/s \ \hat{i}$
$\vec{a} = -4 \times 10^{30} \ m/s^2 \hat{i}$
$b = 3.0 \times 10^{-15} \ m$
$R_{Pb} = 7.1 \times 10^{-15} \ m$

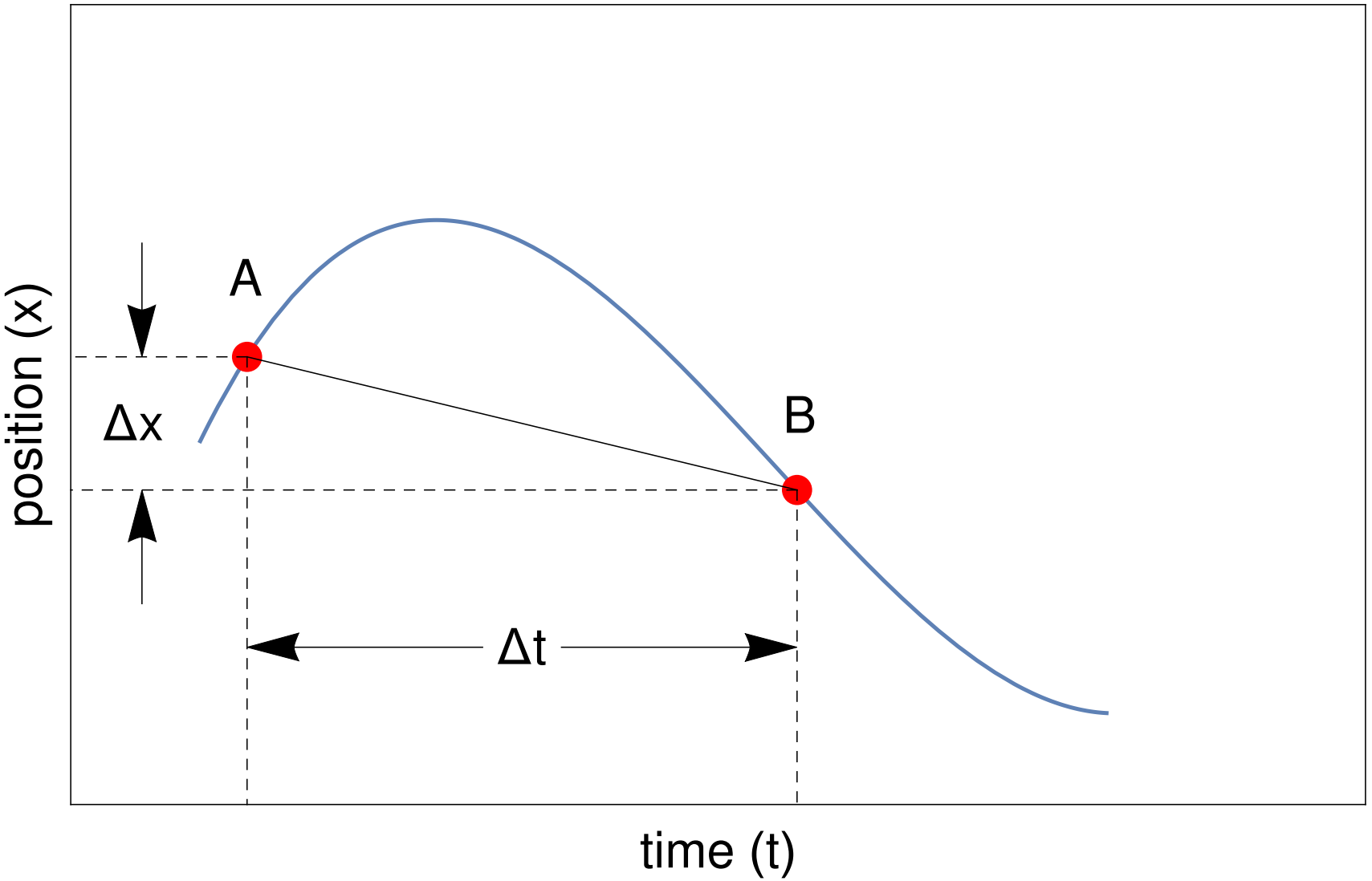


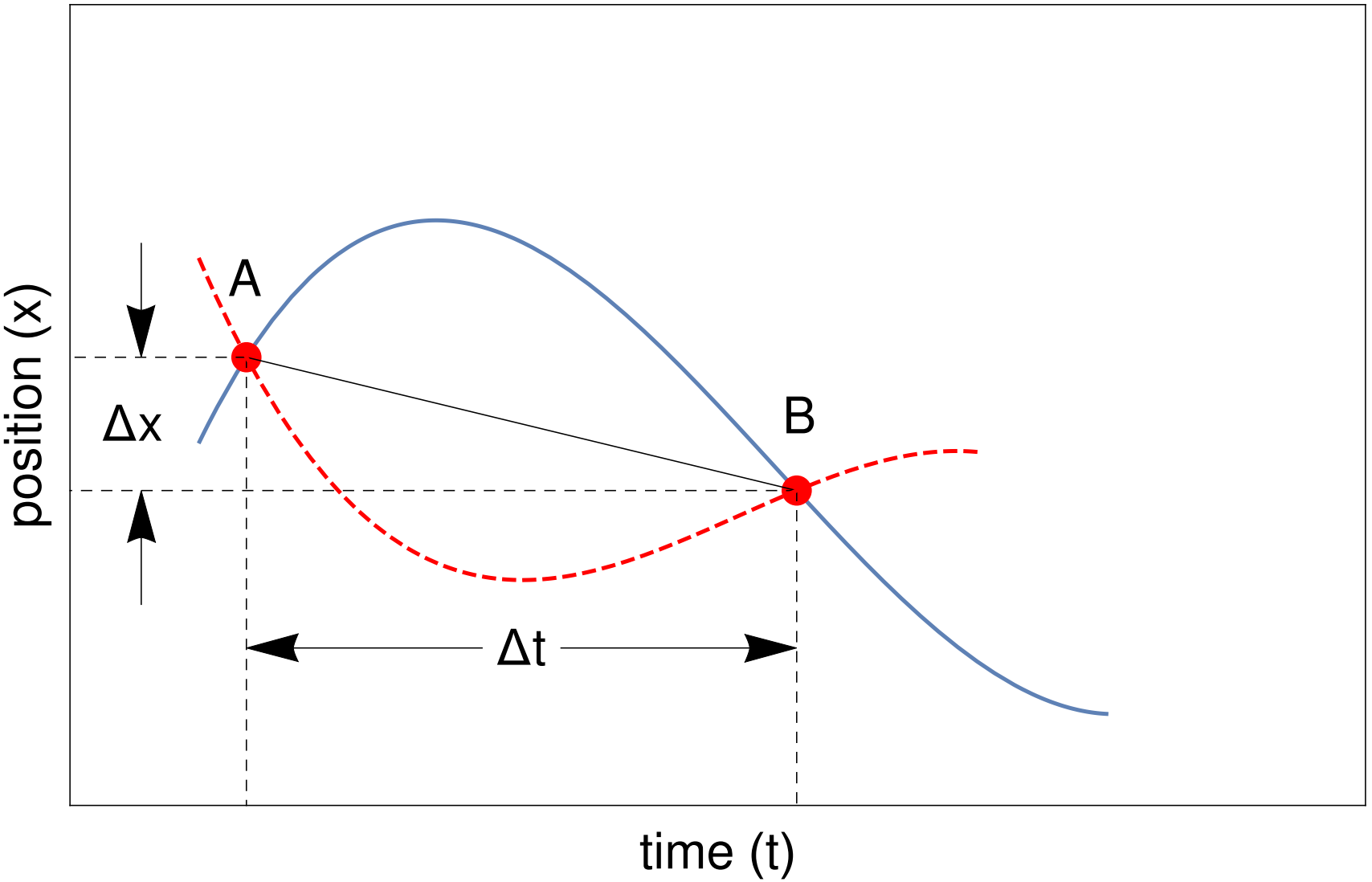
One-Dimensional Motion 9

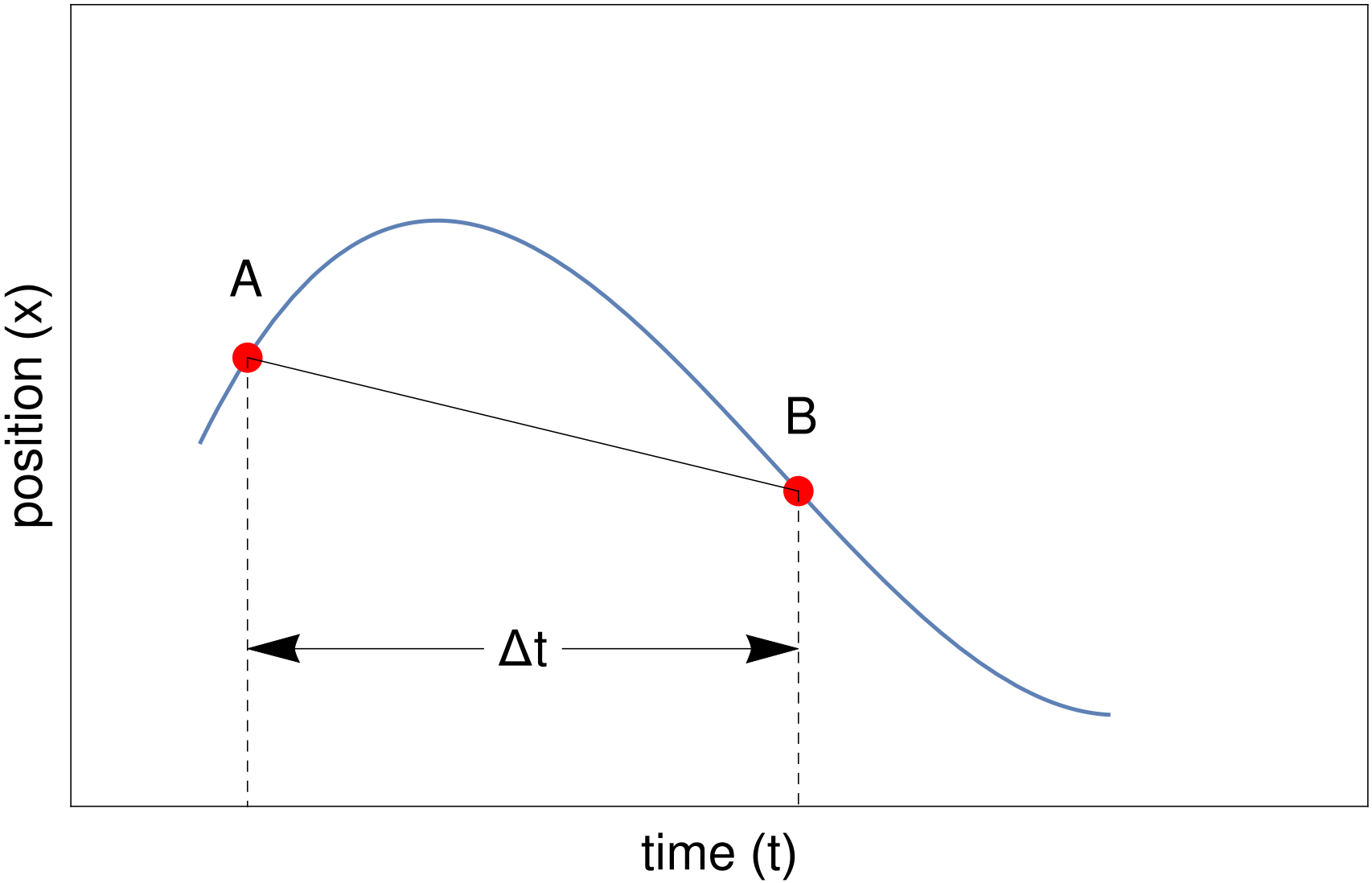


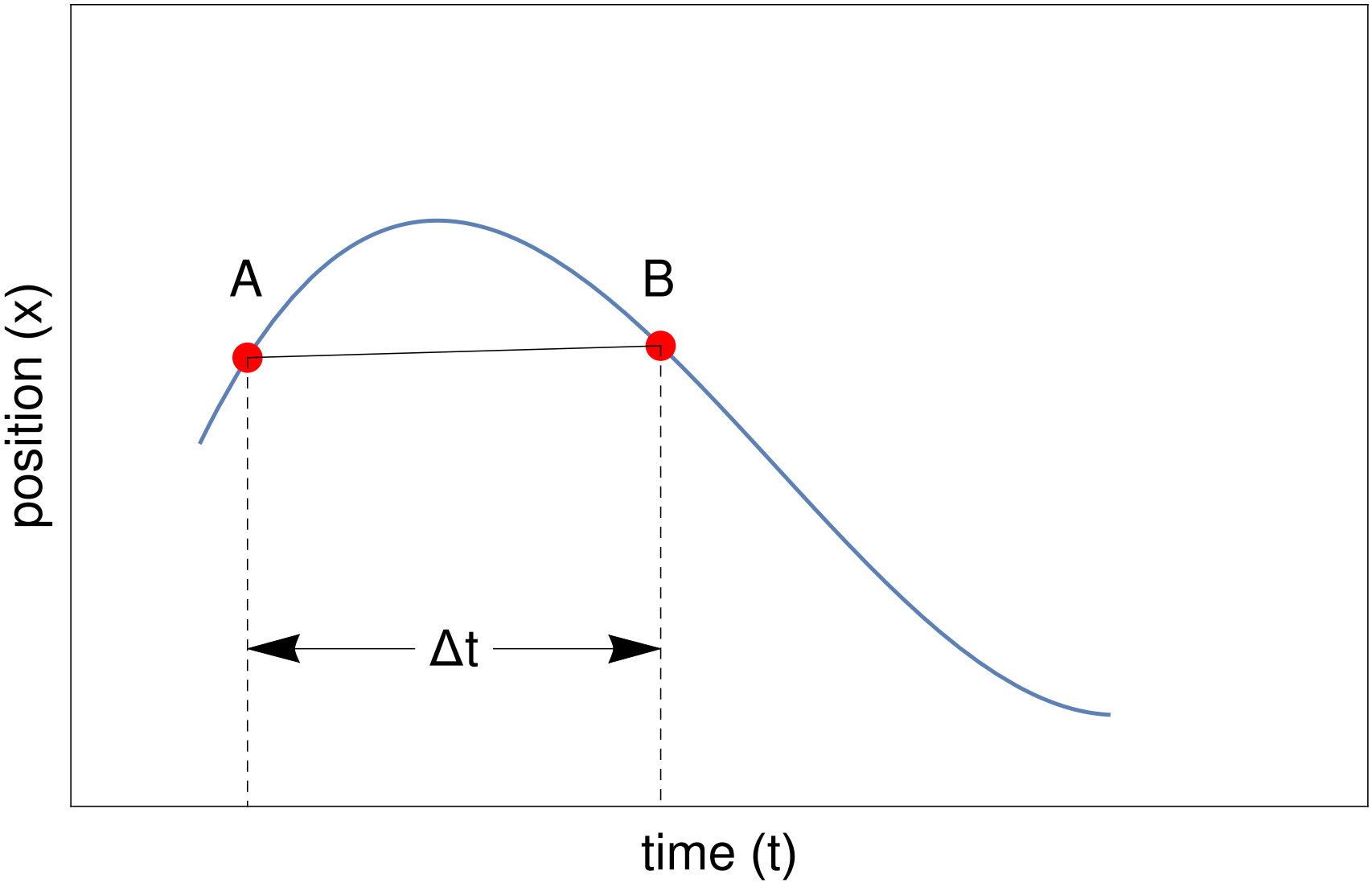

position (x)
A
B
time (t)

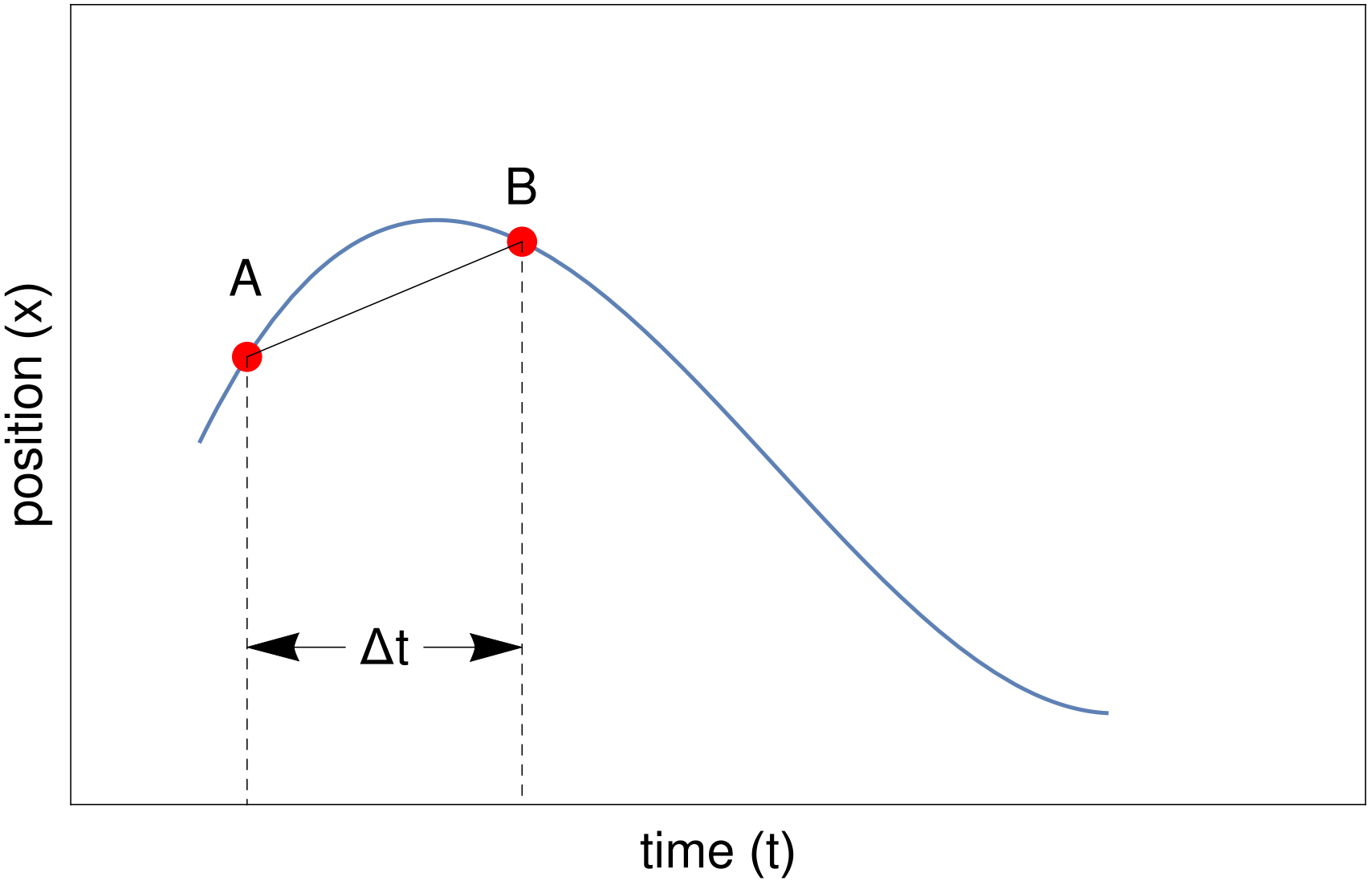

position (x)
A
B
Δt
time (t)

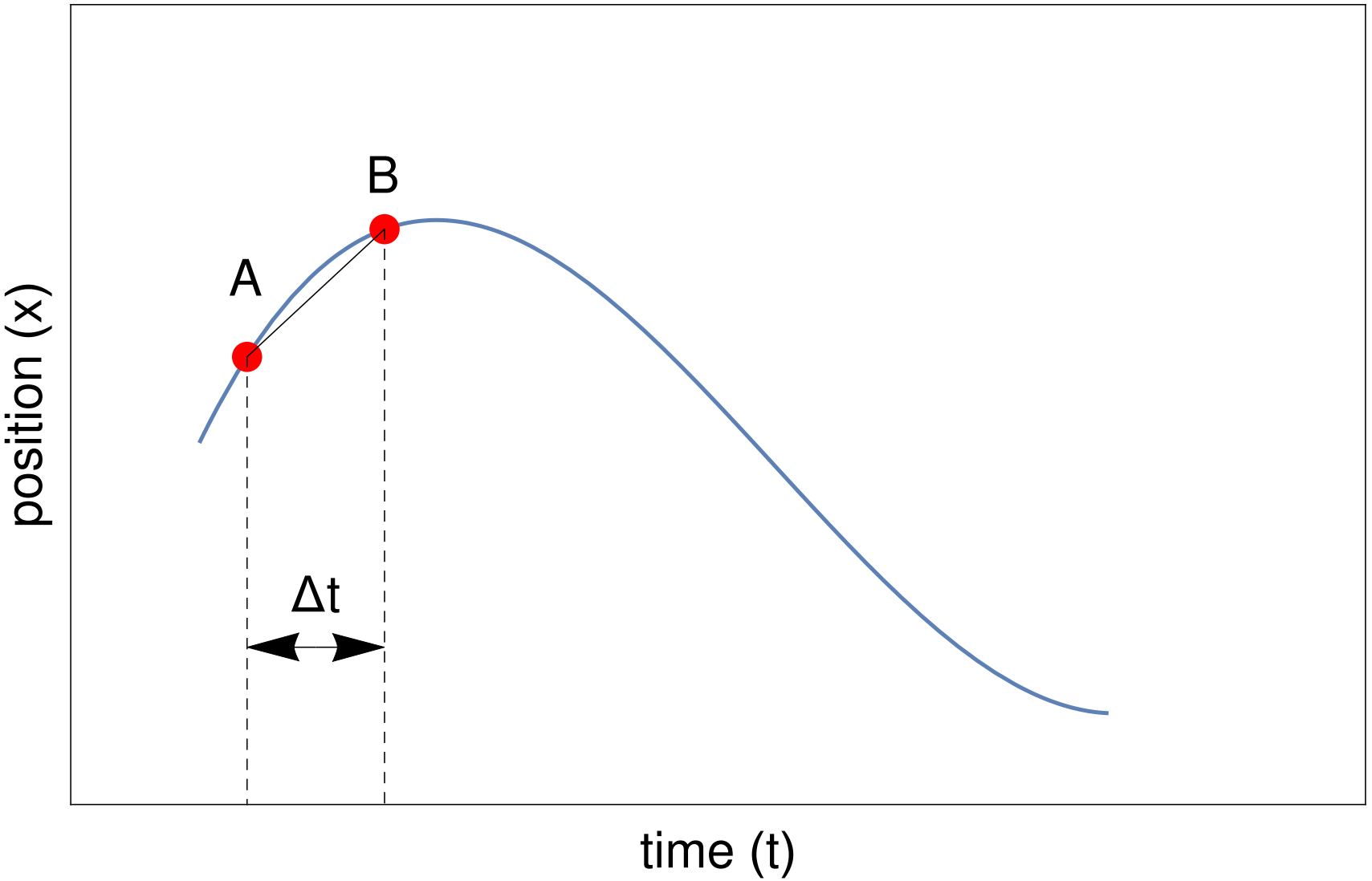

position (x)
A
B
Δx
Δt
time (t)

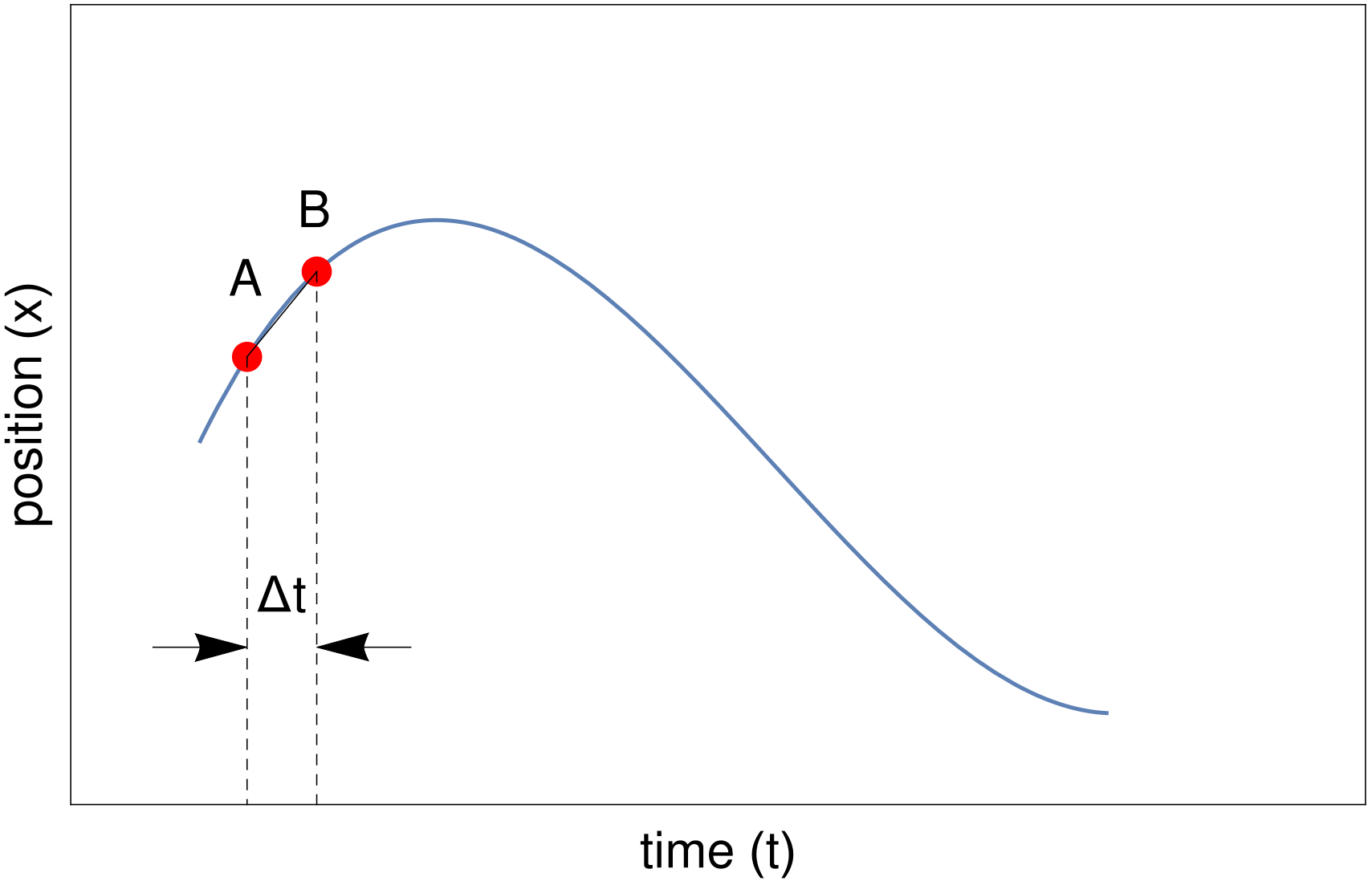

position (x)
A
B
Δx
Δt
time (t)

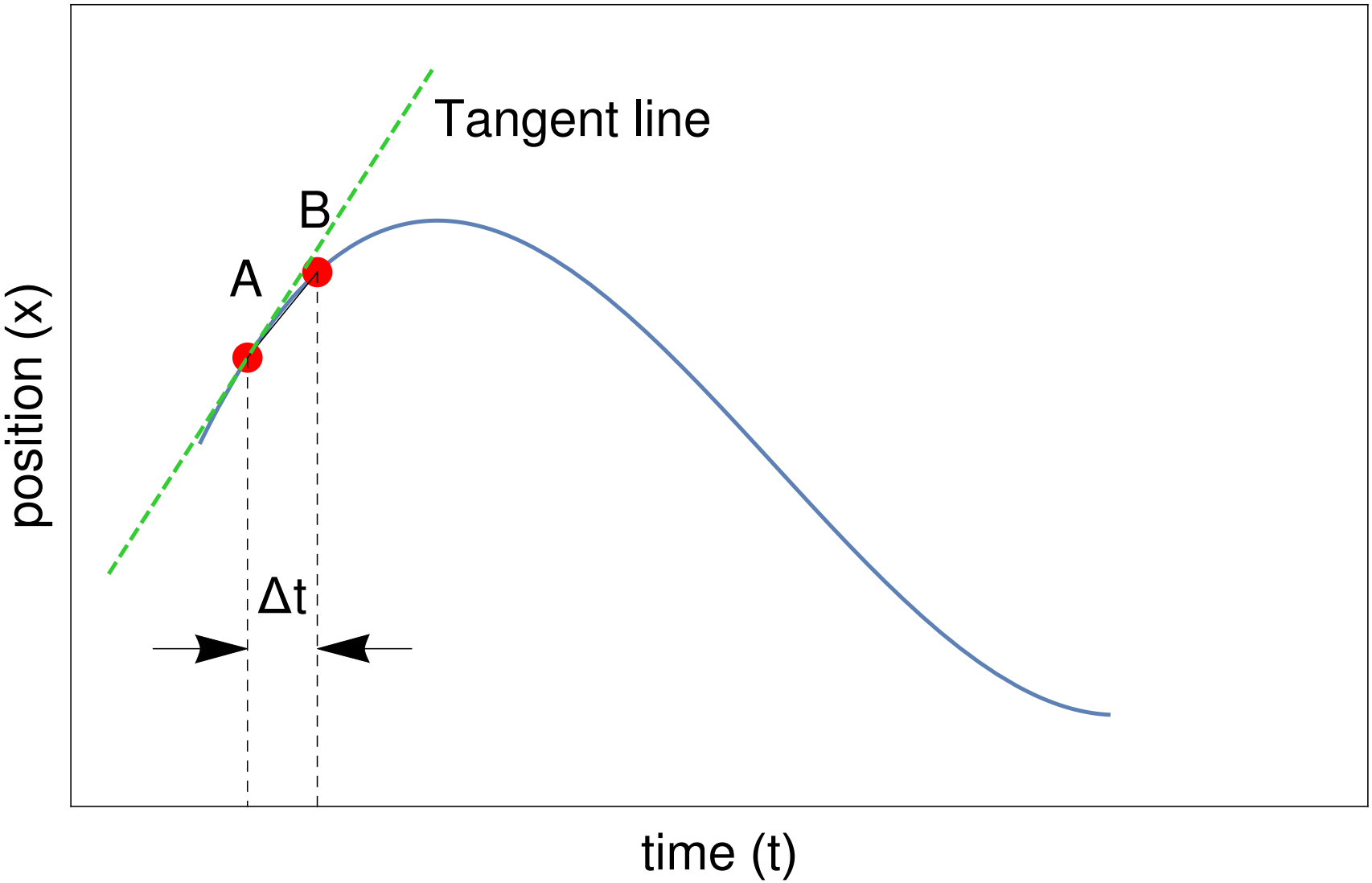

position (x)
A
B
Δt
time (t)

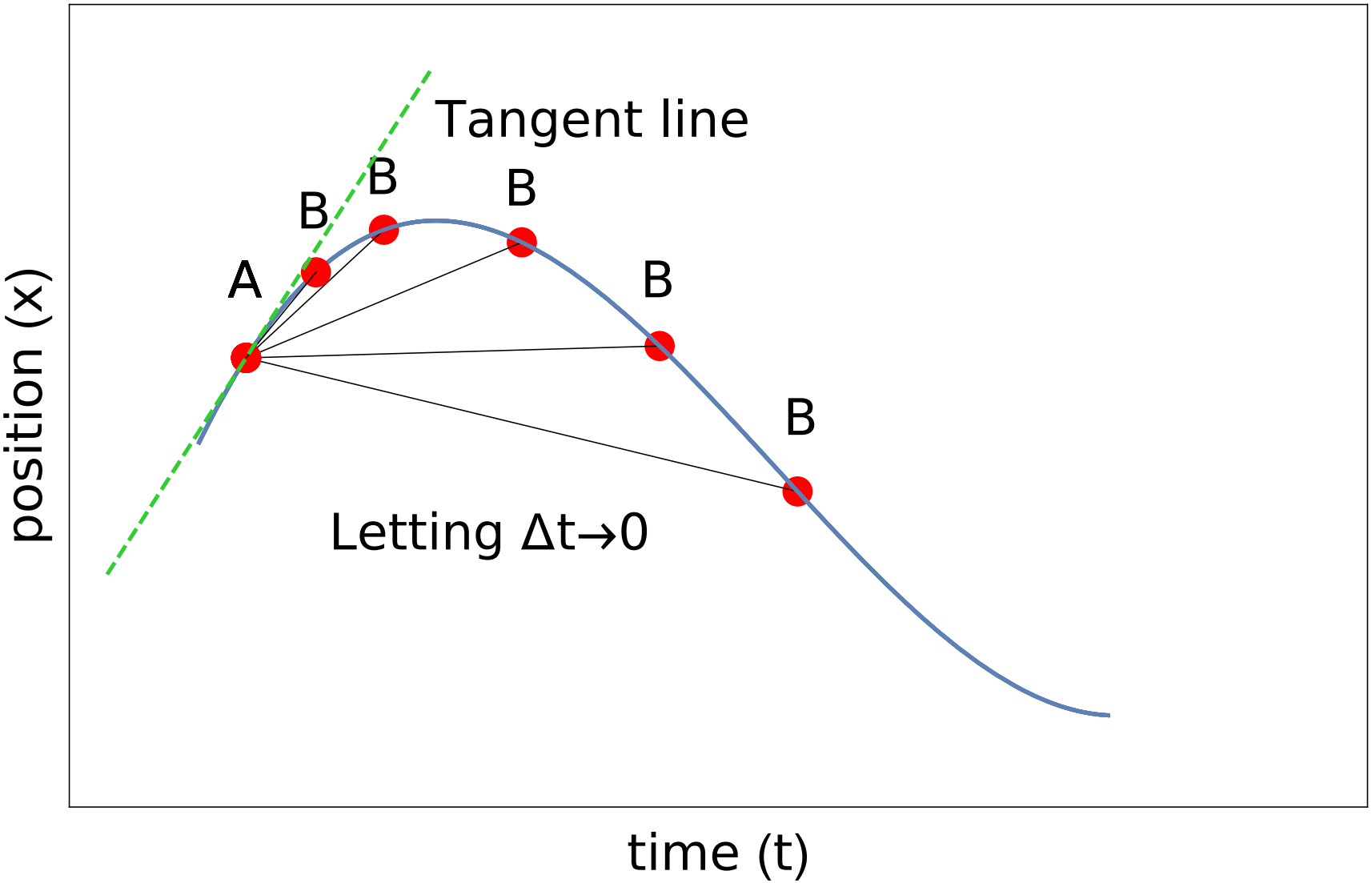

position (x)
A
B
Δt
time (t)


B
A
position (x)
Δt
time (t)


B
A
position (x)
Δt
time (t)


B
A
Δt
position (x)
time (t)


Tangent line
B
A
Δt
position (x)
time (t)

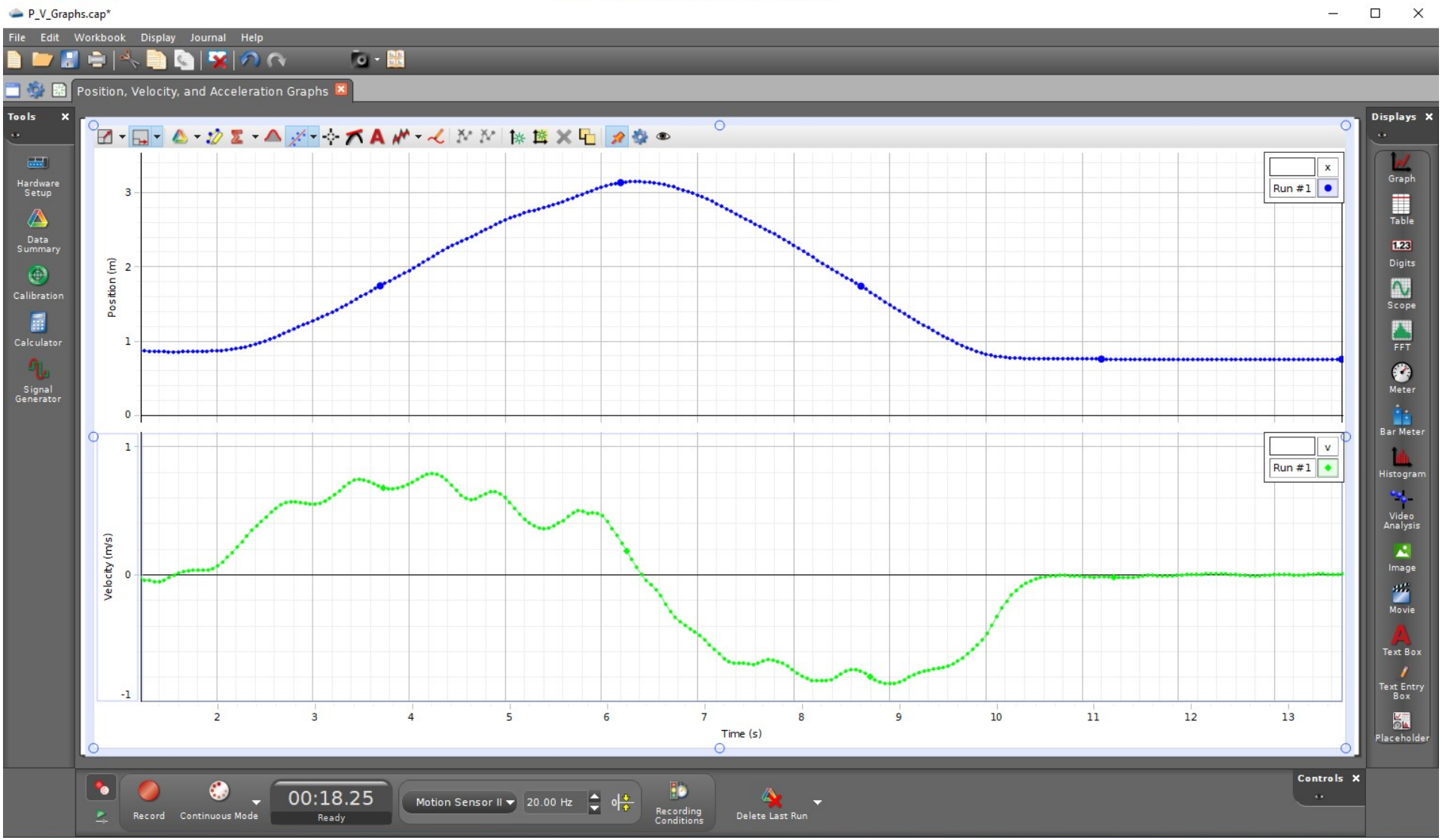

Tangent line
B
B
B
B
B
A
Letting Δt→0
position (x)
time (t)

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

Position and Velocity 22



Captain Kirk's Bad Day 23

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

What is the instantaneous acceleration?

Do the velocity and acceleration versus time plots make sense?

Catching Up 24

At the instant a traffic light turns green, a 'car' starts with a constant acceleration $a = 2.2\ m/s^2$. At the same instant a truck is 5.0 m behind the car and traveling with a constant speed $v_t = 9.5\ m/s$. 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?

Catching Up 25

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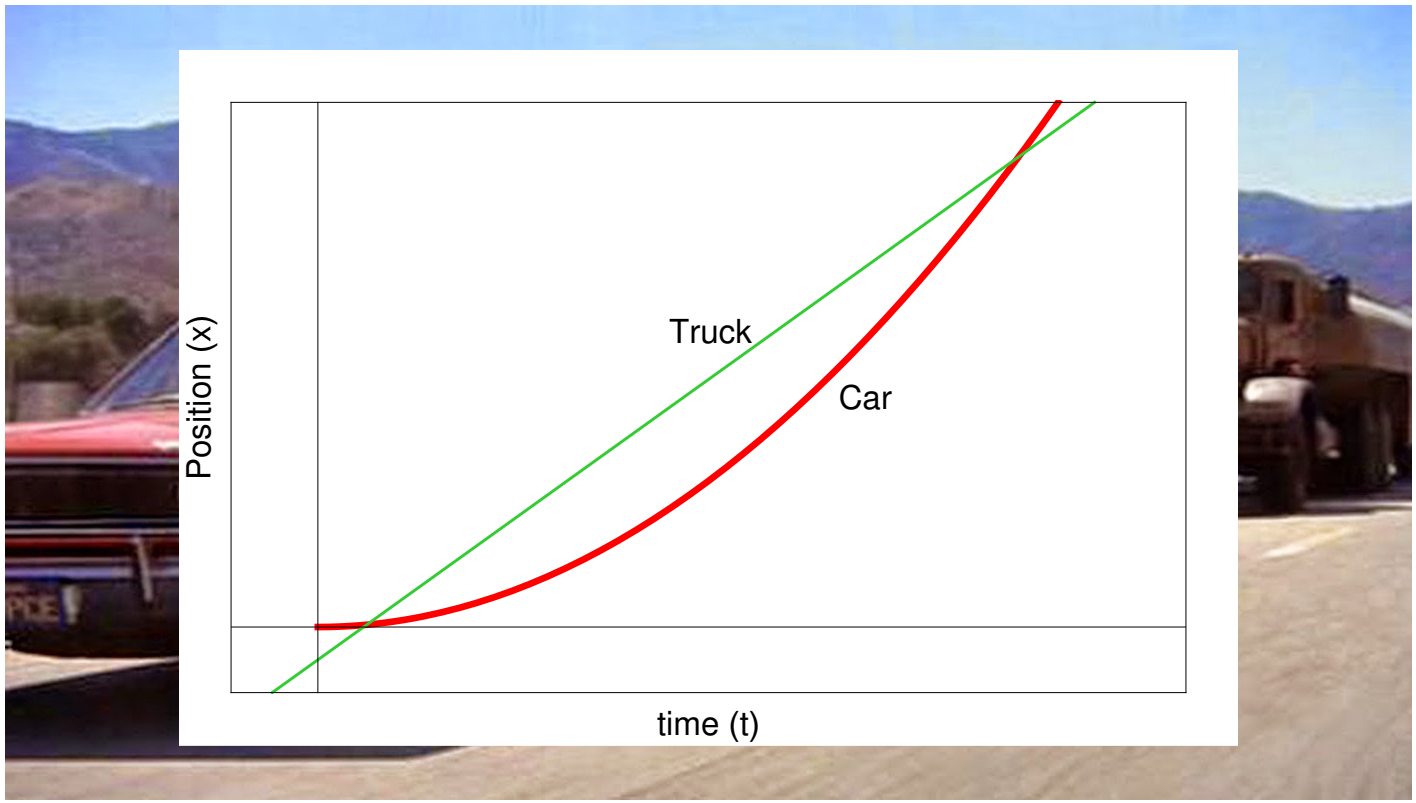
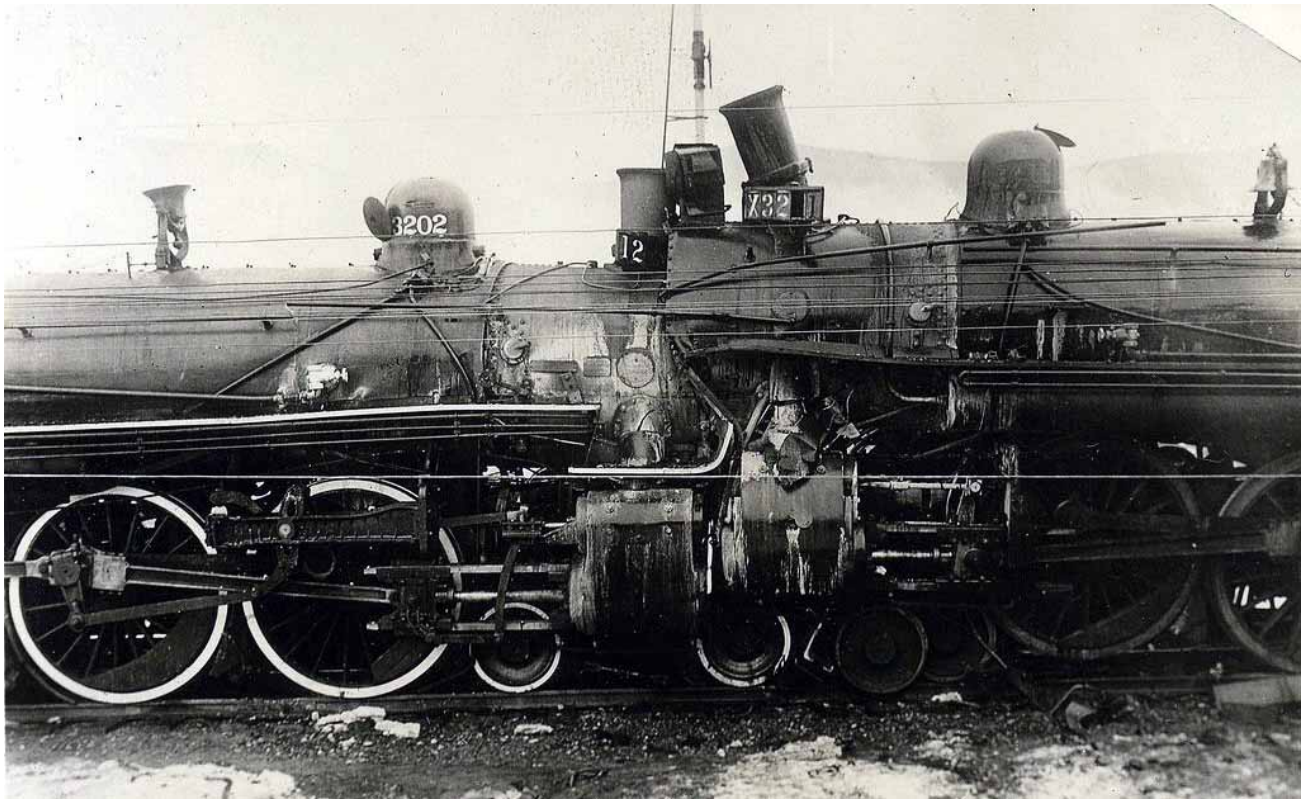


EEEEKKK!! 26

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?



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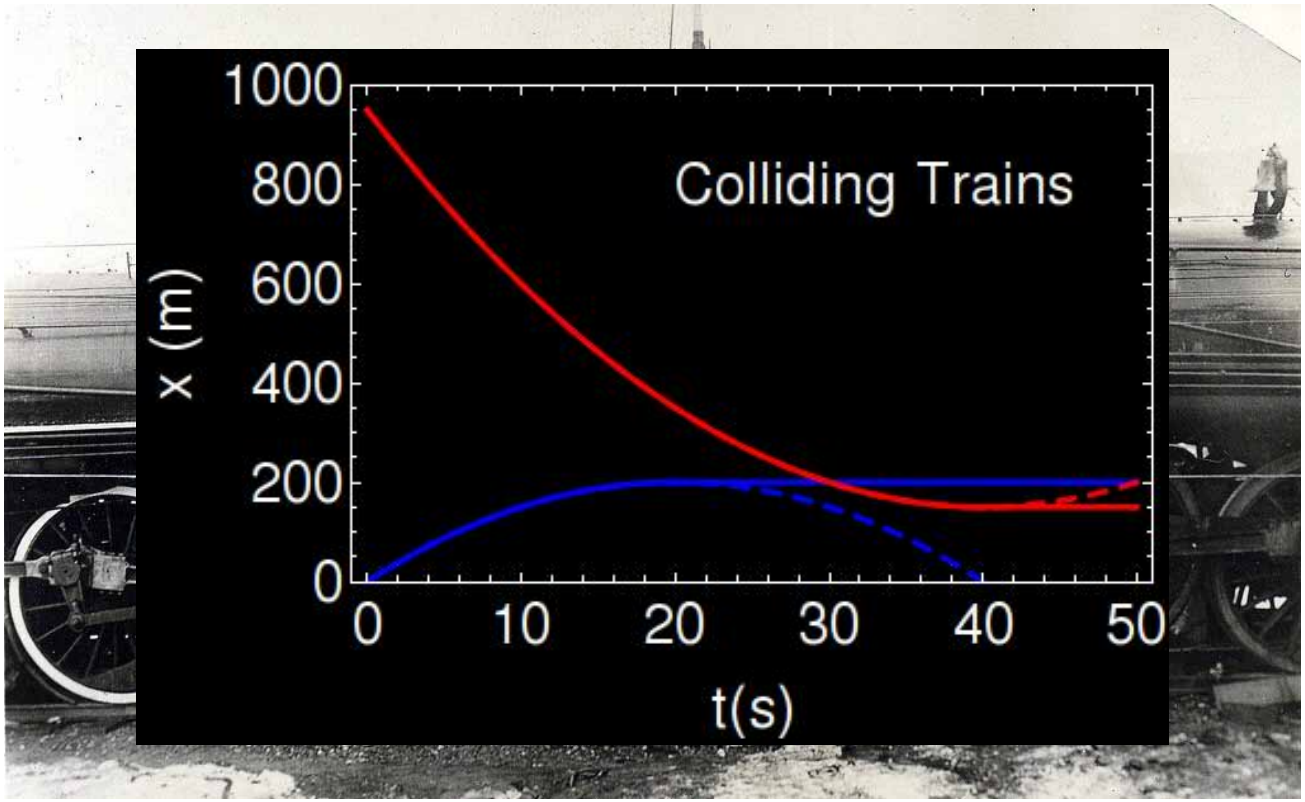
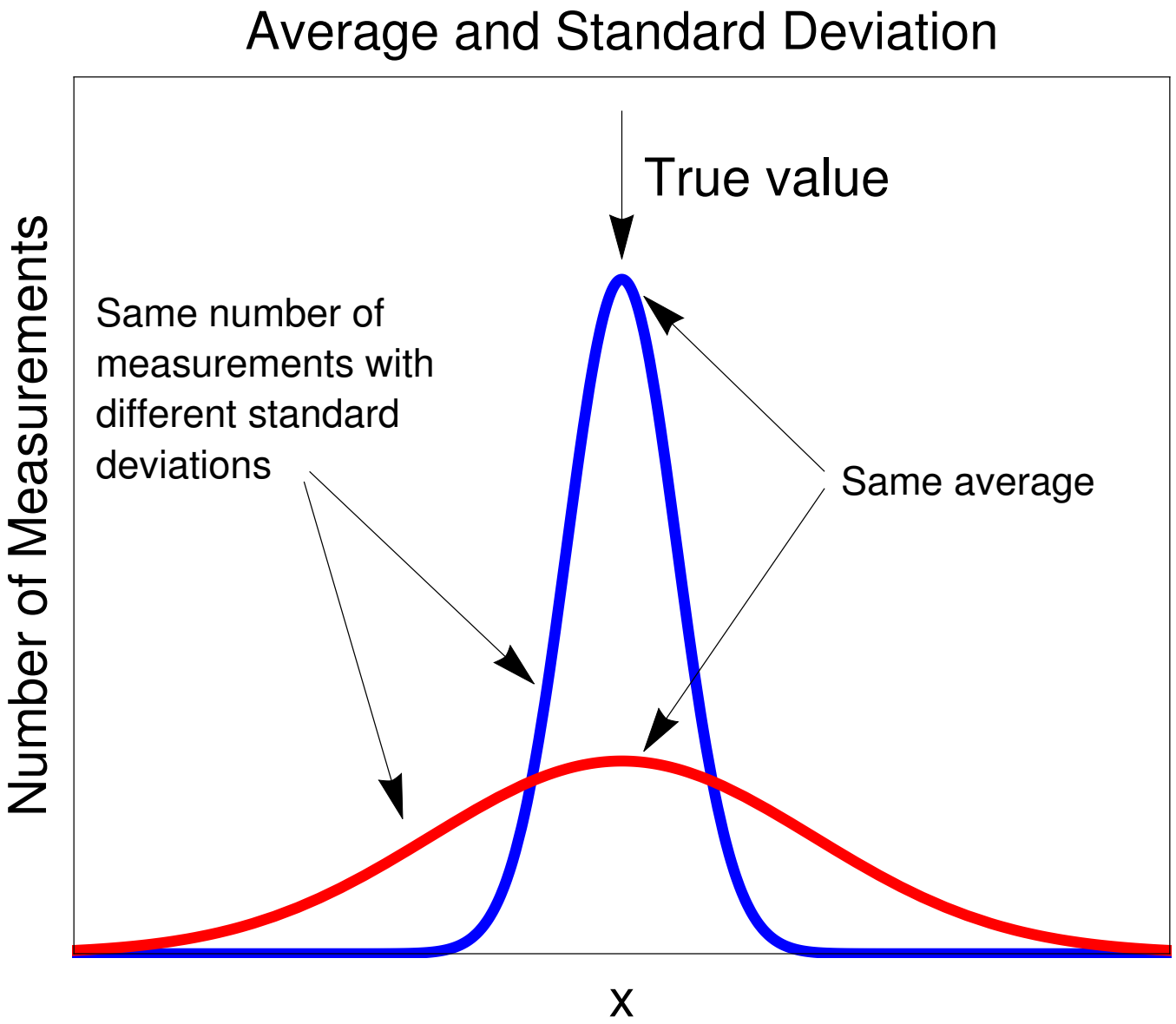
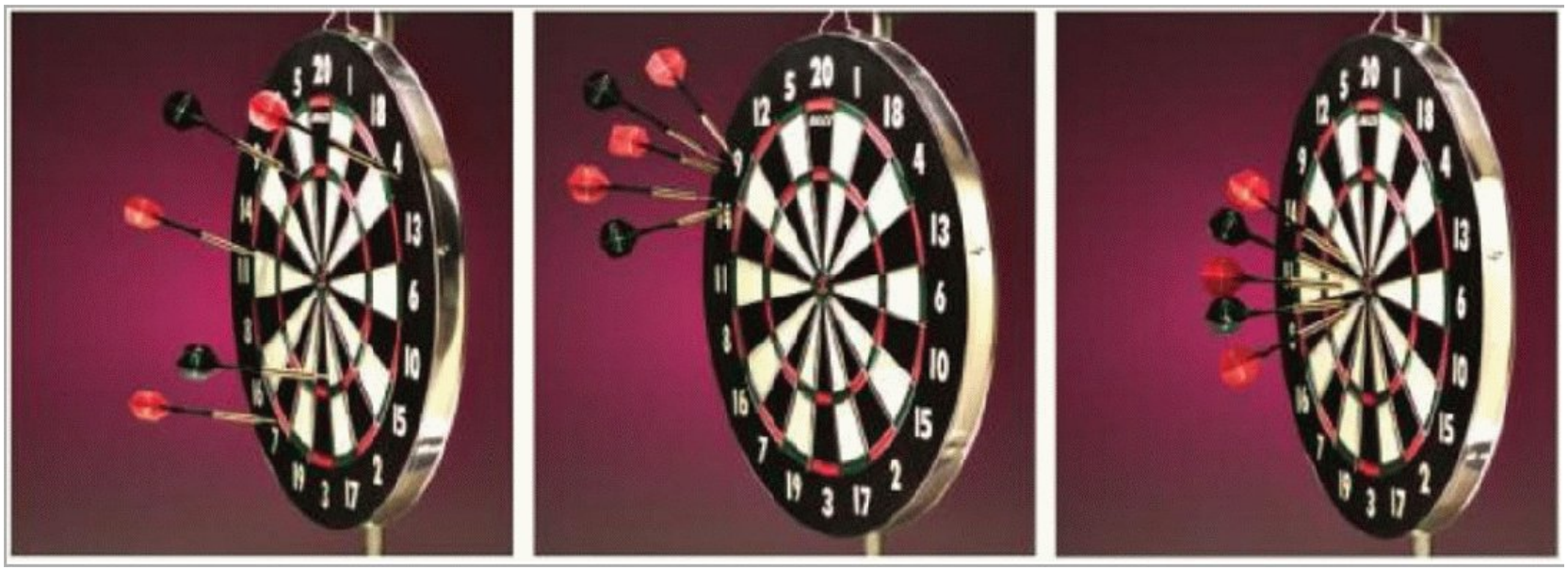


Don't Do This At Home 28

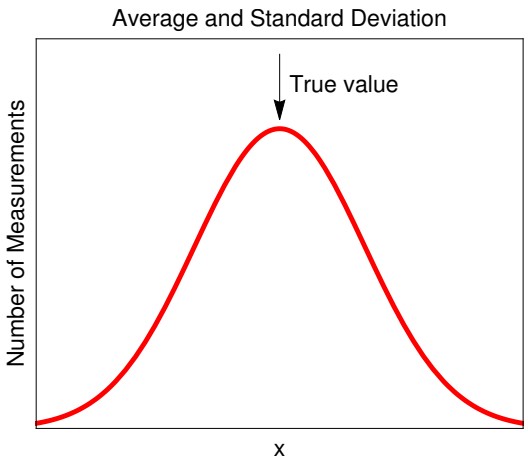
A window washer named Chris Sagger is reported to have fallen (assume starting from rest) 67 meters from a building where he was working, landed on a car, and lived. Suppose the roof of the car was compressed 1.45 m. Ignoring air resistance what is his speed just before hitting the car? Treating his 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
True value
Same number of measurements with different standard deviations
Same average
Number of Measurements
x

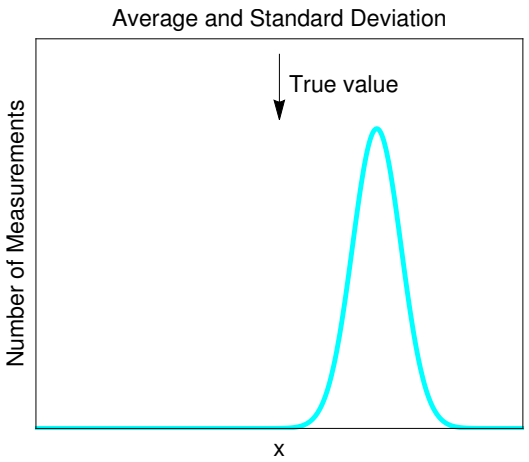
Precision versus Accuracy 30



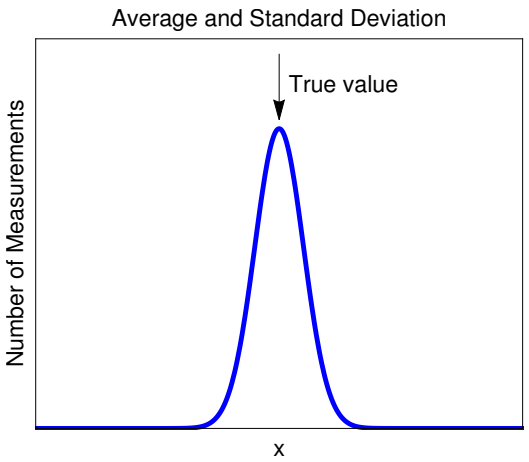
Not precise.

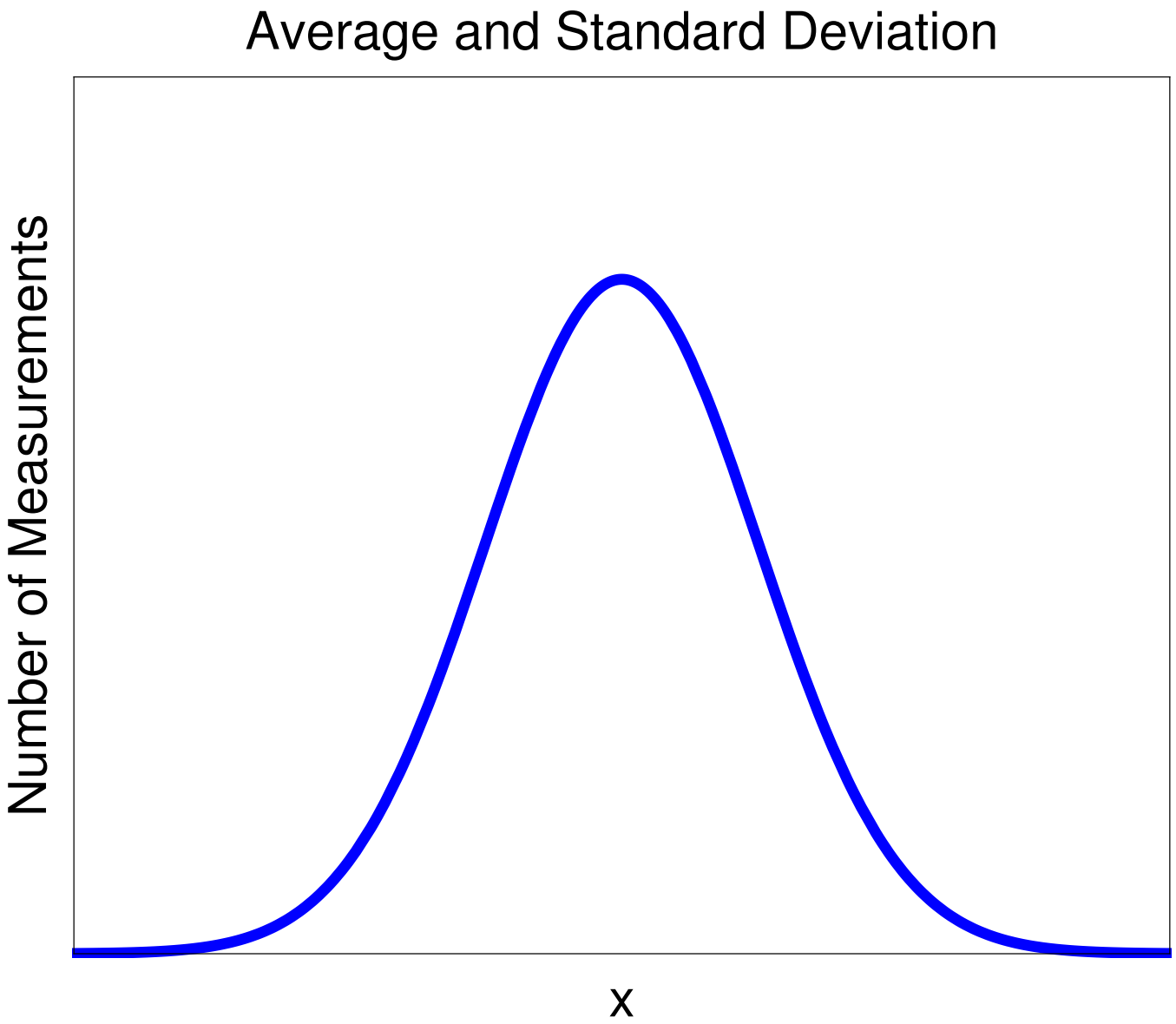


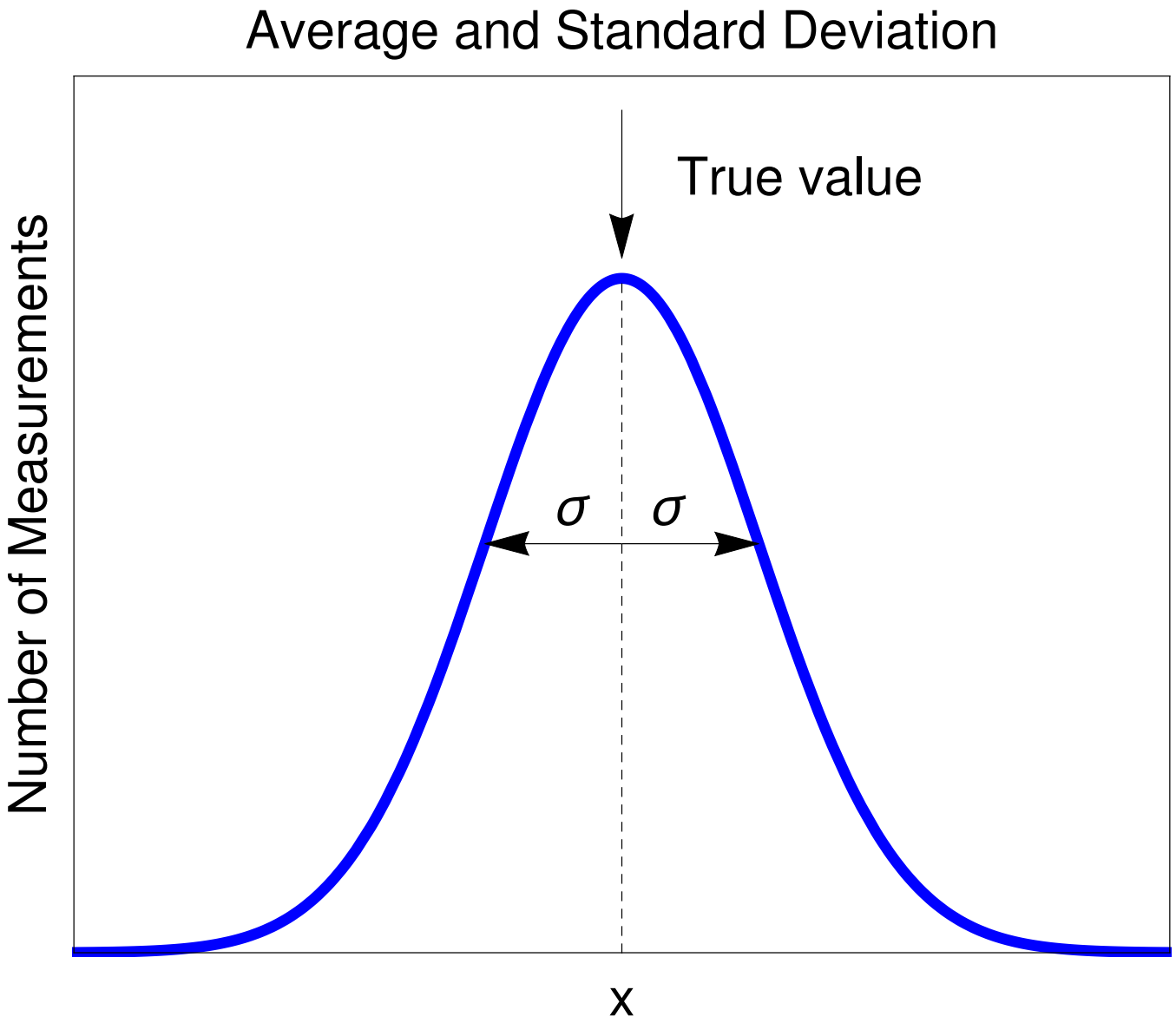
Precise, but not accurate.

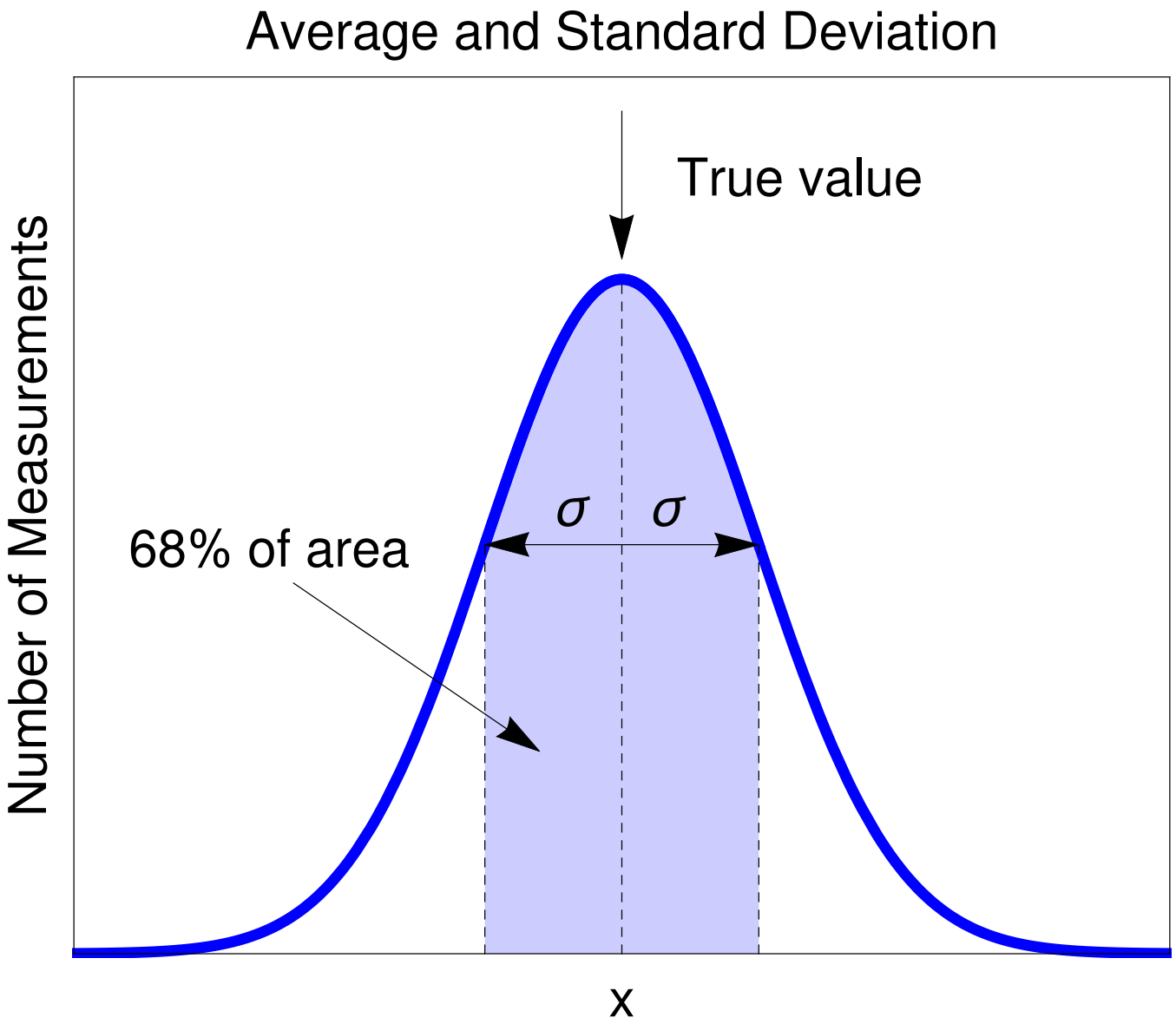


Precise and accurate.




Average and Standard Deviation
Number of Measurements
x

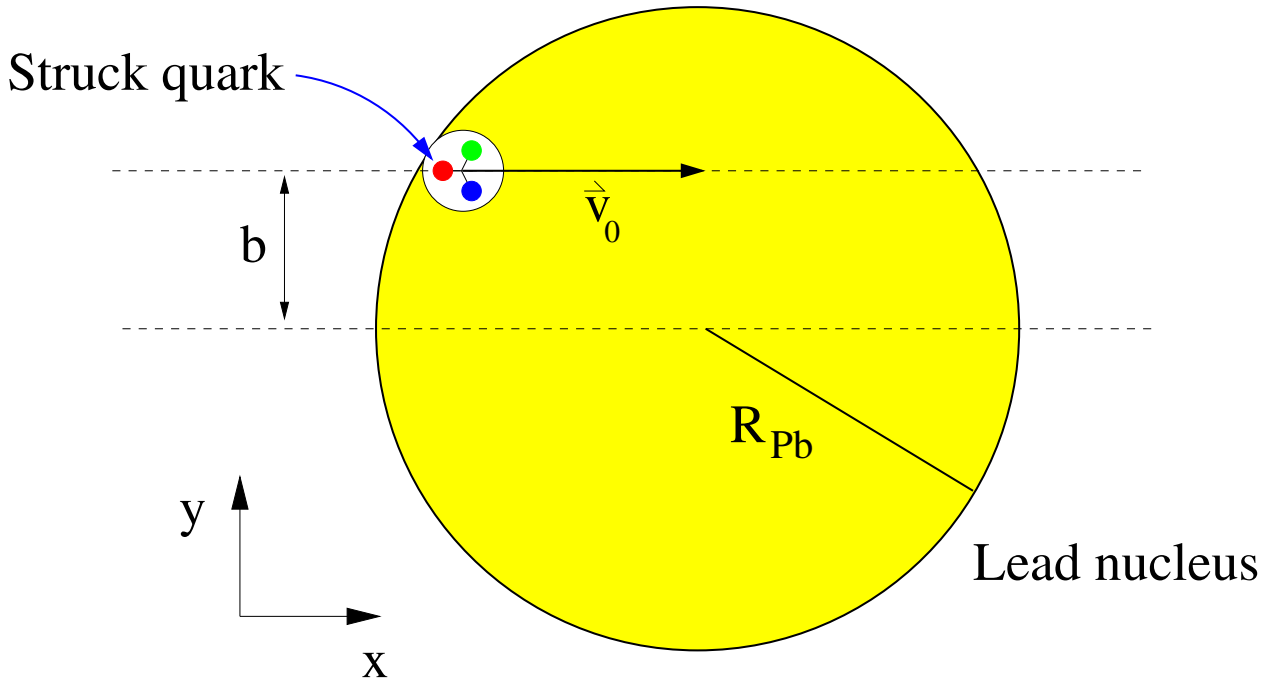

Average and Standard Deviation
True value
σ
σ
Number of Measurements
x


Average and Standard Deviation
True value
Number of Measurements
68% of area
σ
σ
x

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 $\vec{v}_o$ 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?

$v_o = 3 \times 10^8\ m/s$
$|a| = 4 \times 10^{30}\ m/s^2$
$b = 3.0 \times 10^{-15}\ m$
$R_{Pb} = 7.1 \times 10^{-15}\ m$



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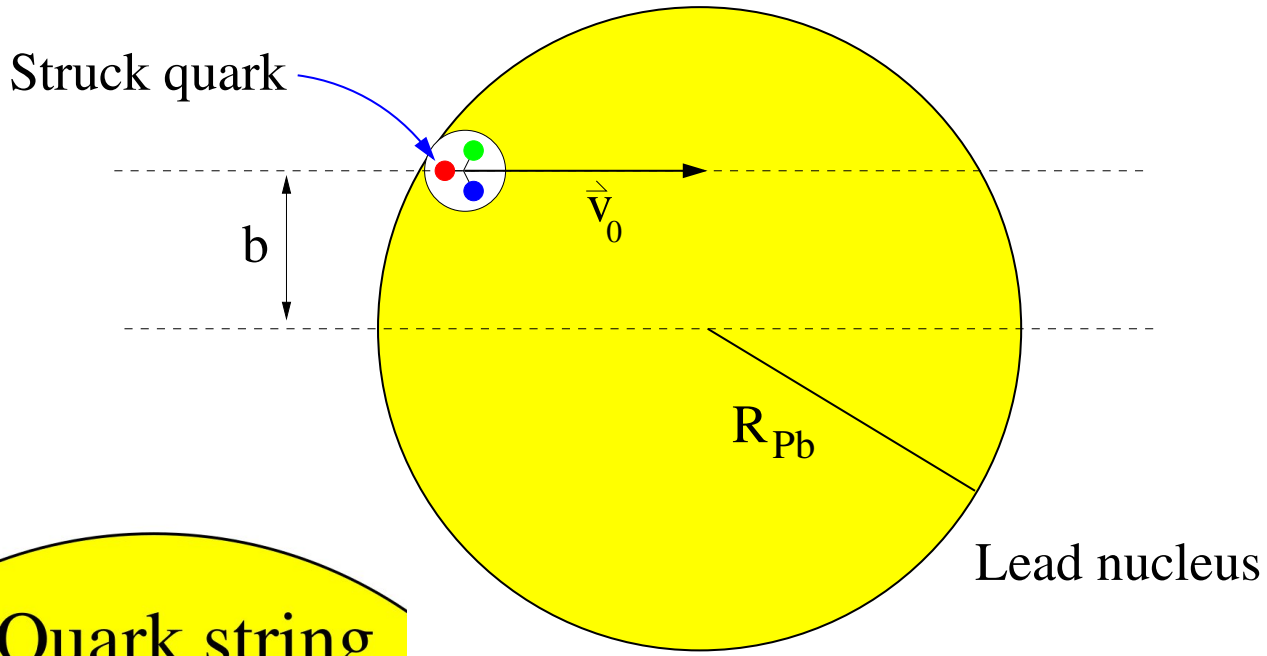
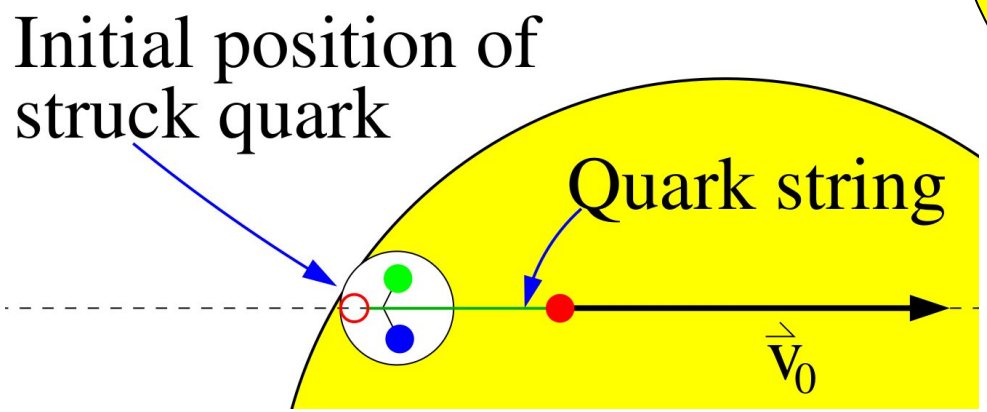
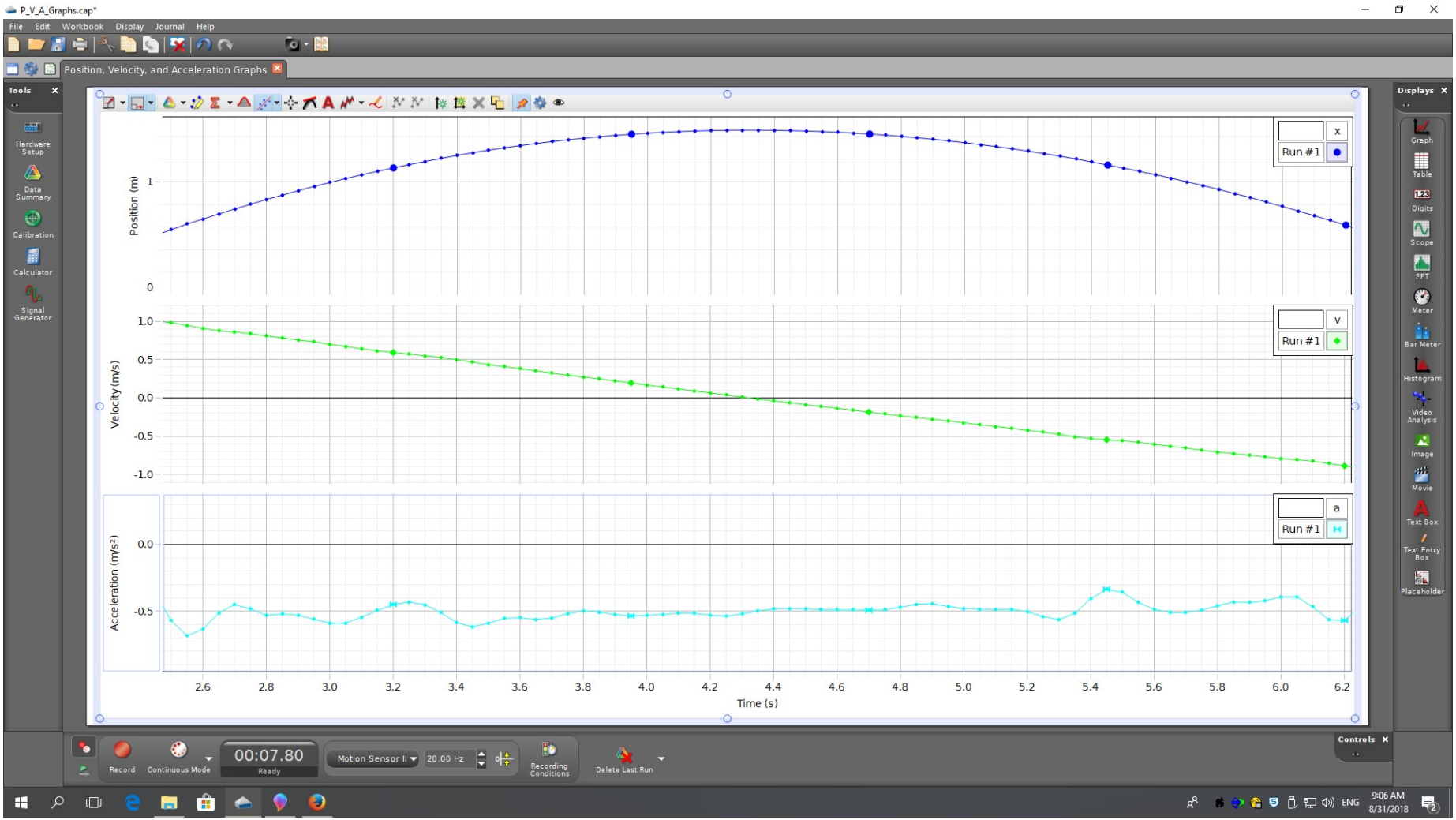
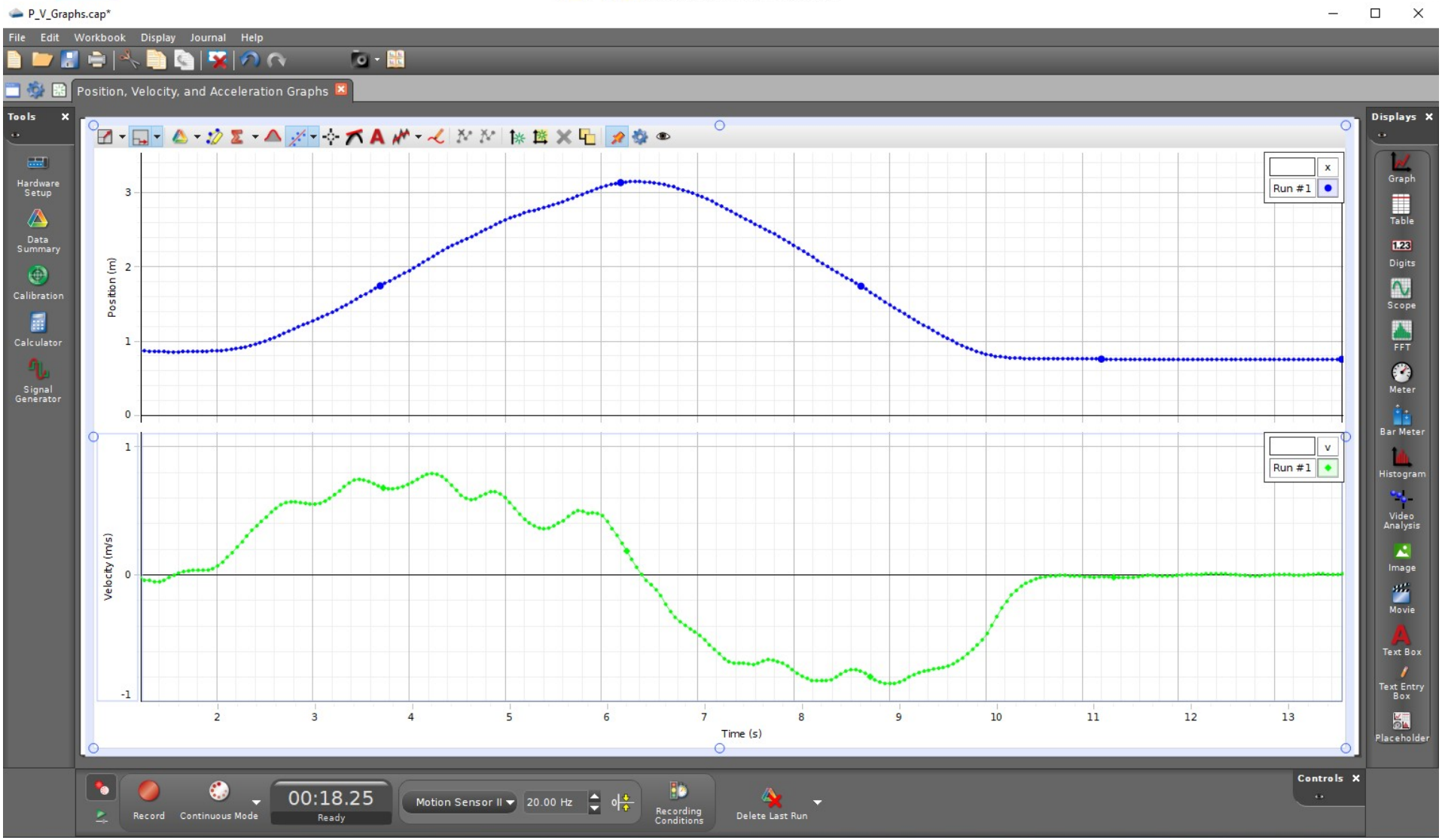




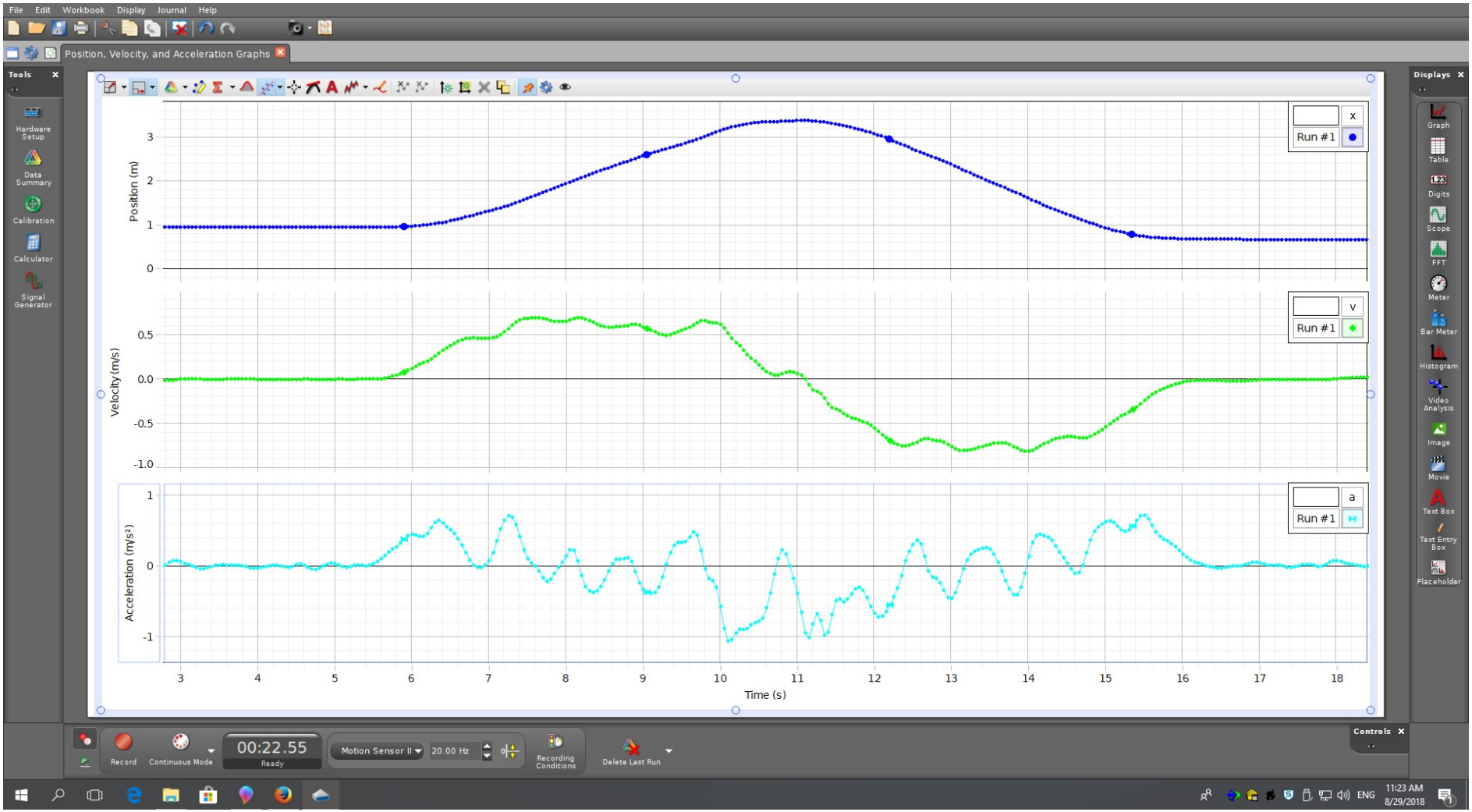
Turning Around 1 36



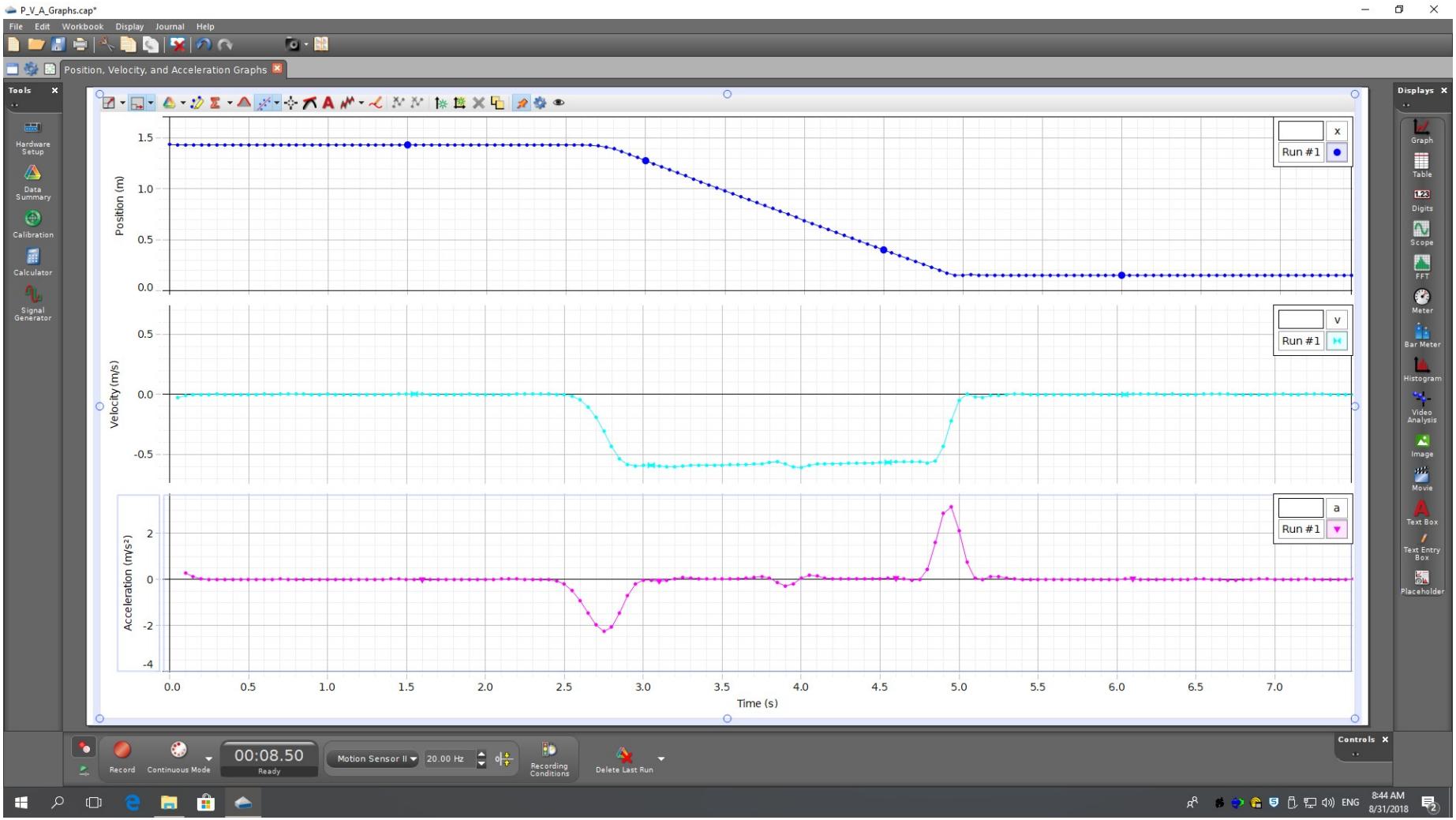
Position and Velocity 37



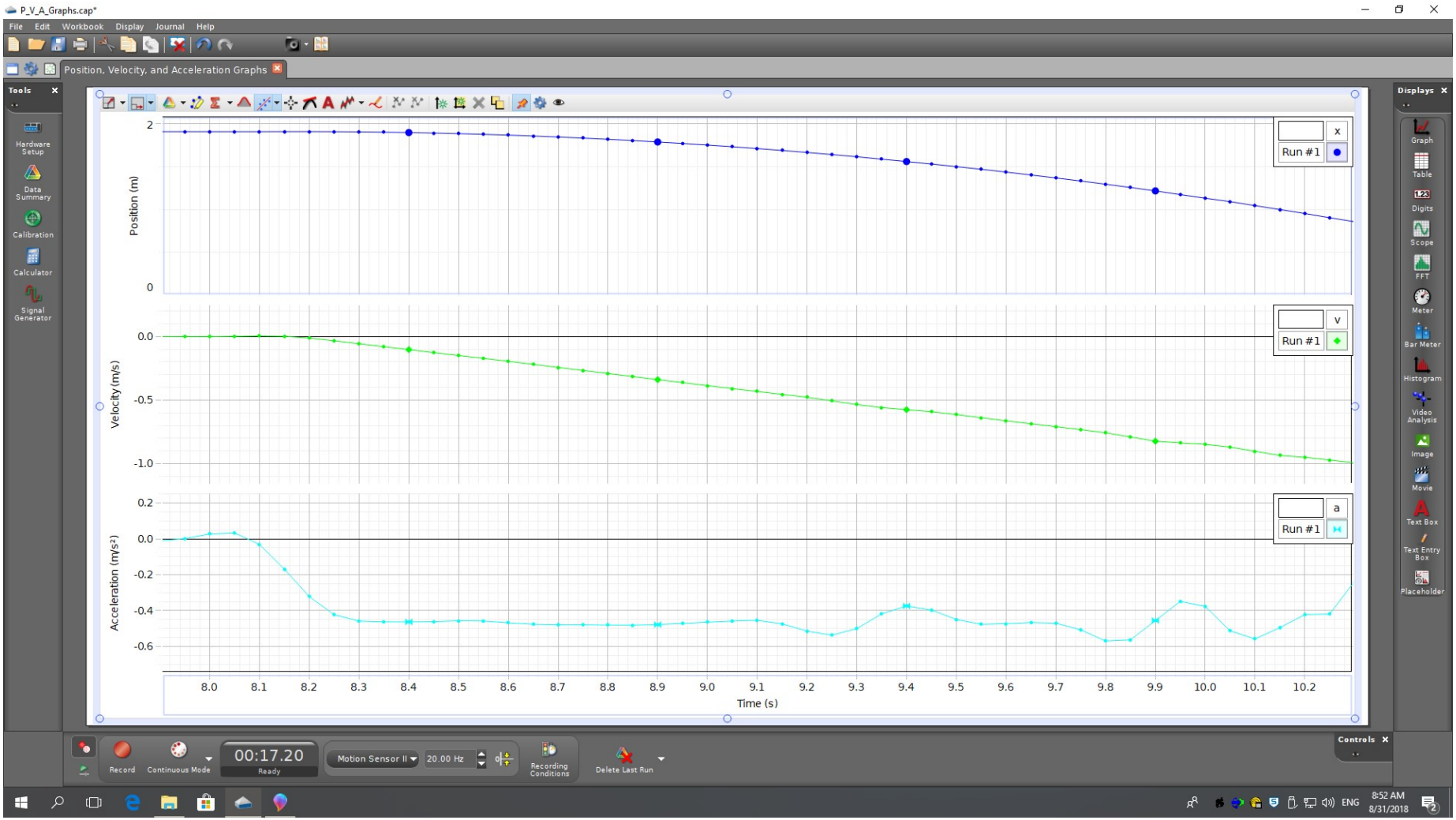
Changing Motion 38



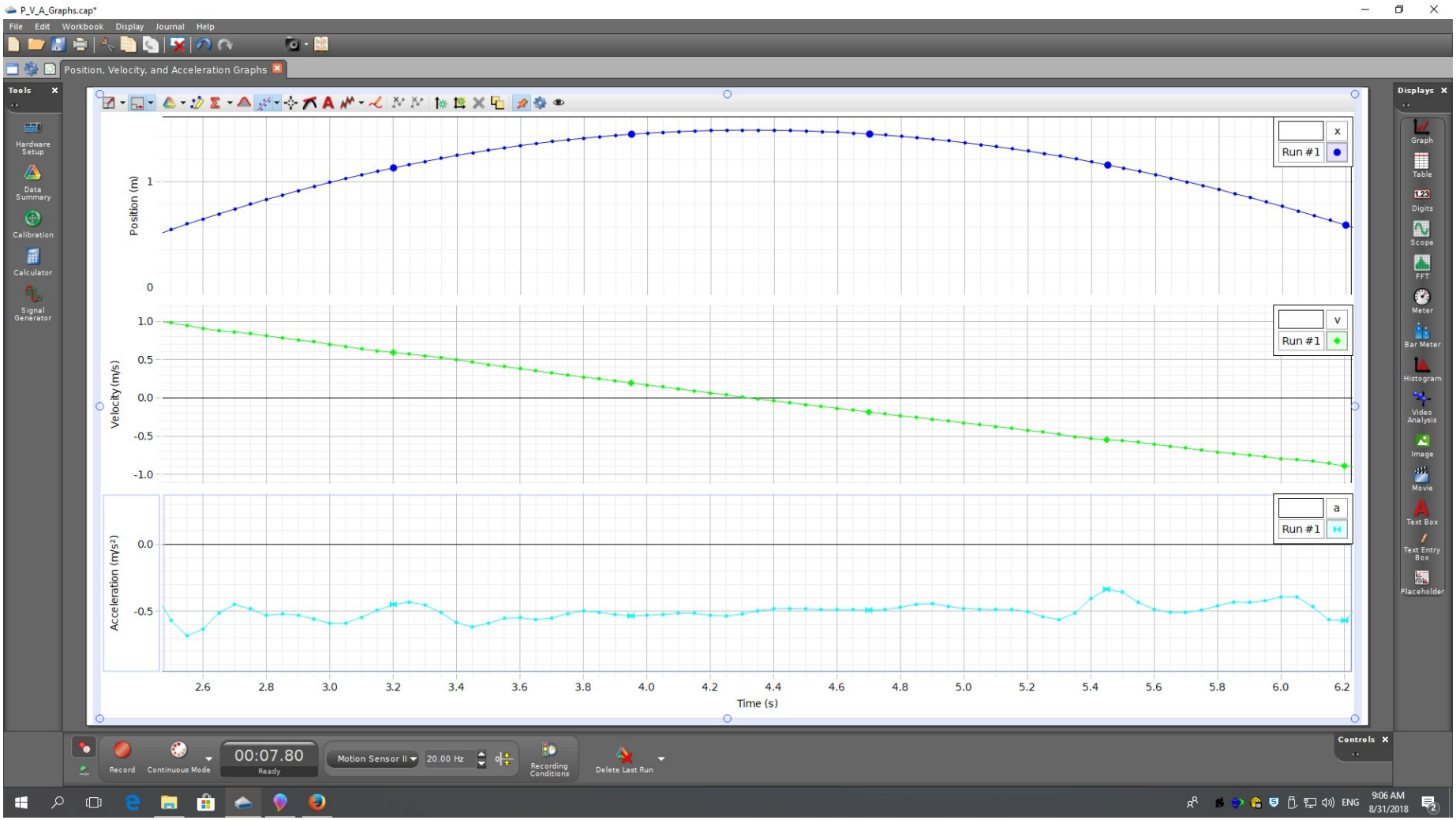
Changing Motion 39



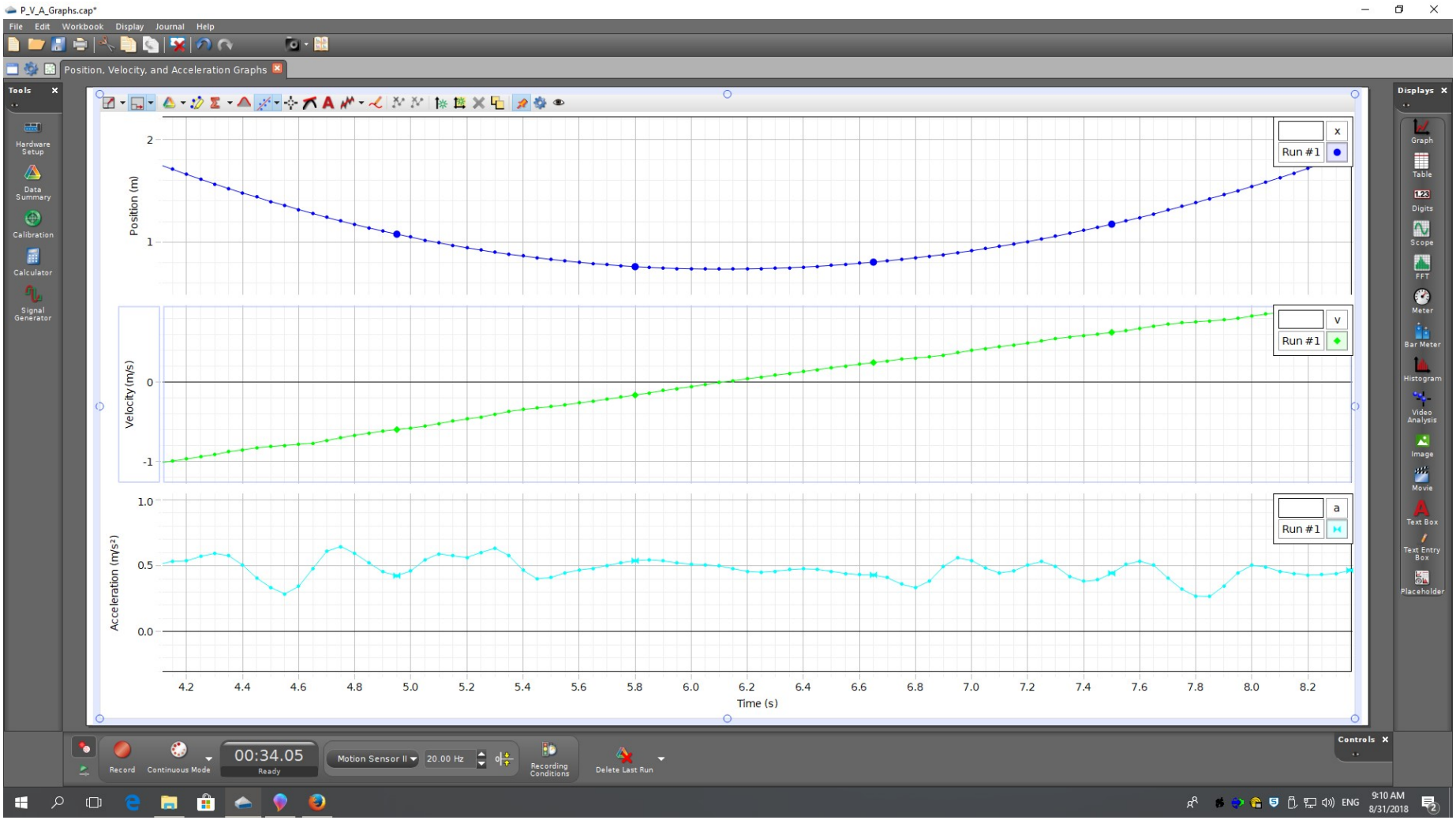
Changing Motion 40



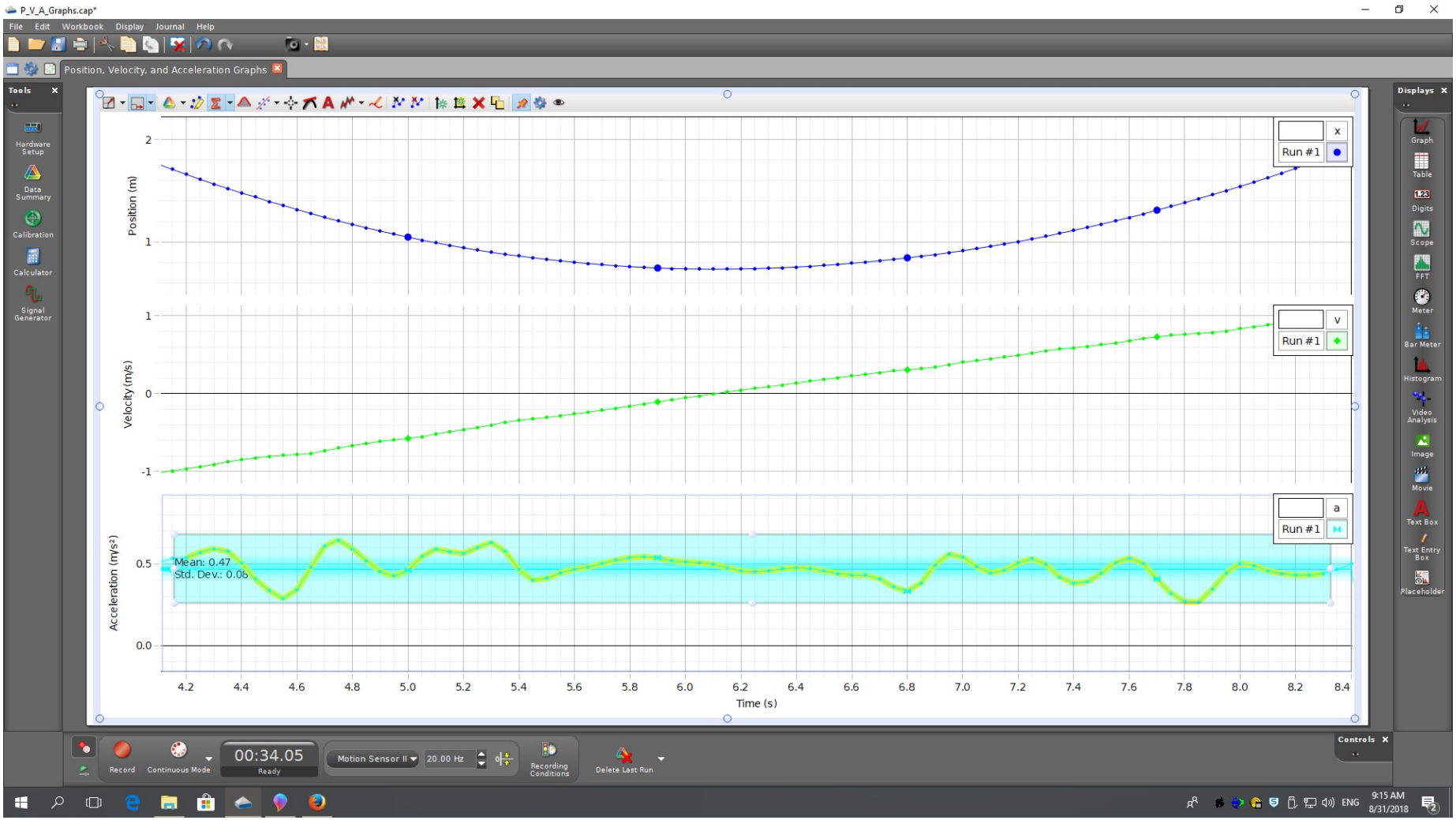
Turning Around 1 41



Turning Around 2 42



Turning Around 3 43



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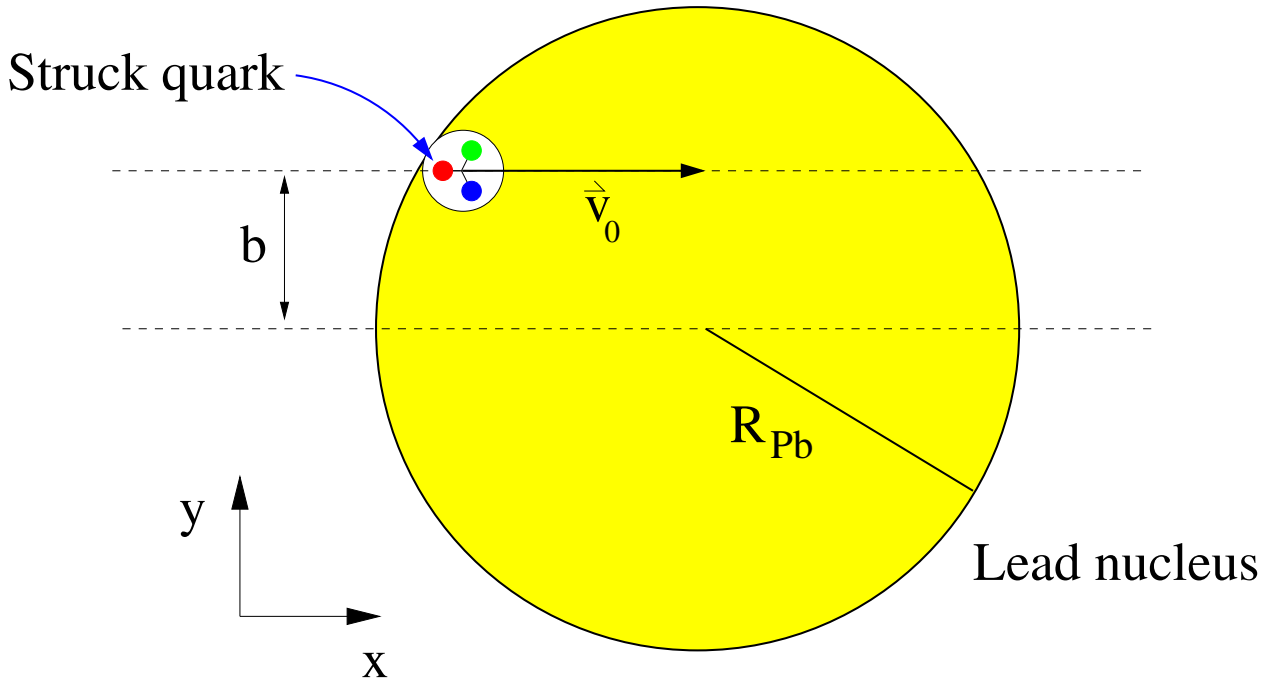
$|a| = 4 \times 10^{30}\ m/s^2$
$b = 3.0 \times 10^{-15}\ m$
$R_{Pb} = 7.1 \times 10^{-15}\ m$



Does the quark escape? 45

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 $\vec{v}_o$ 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?

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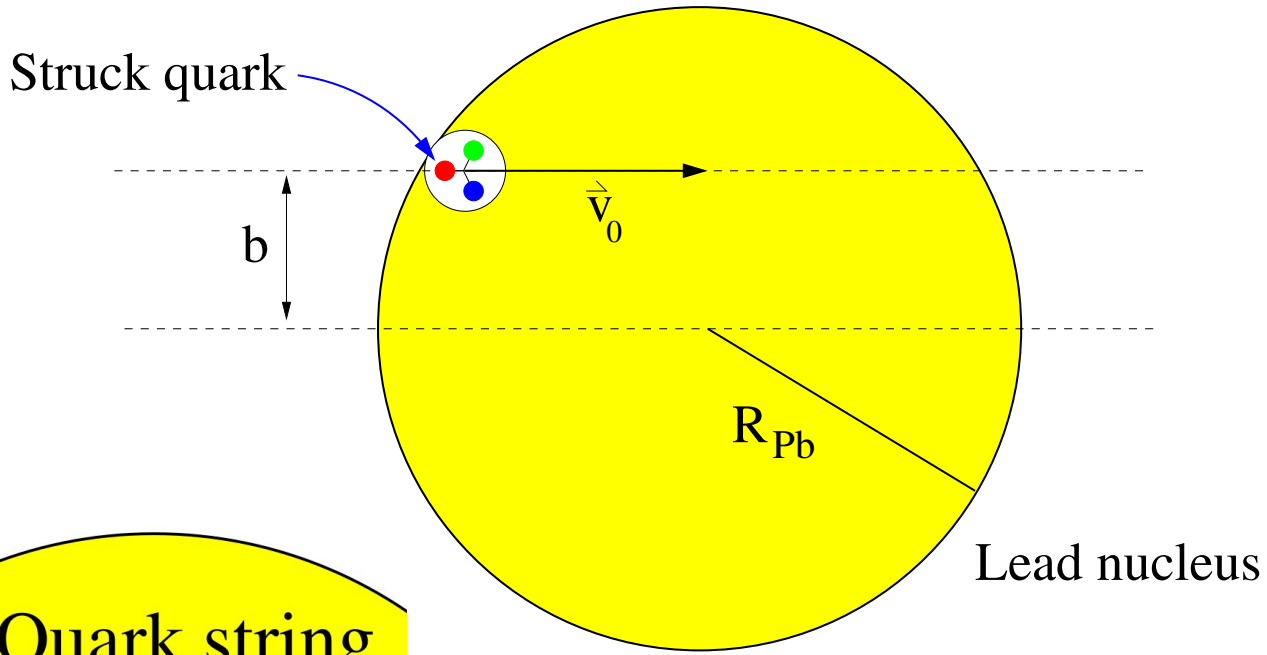

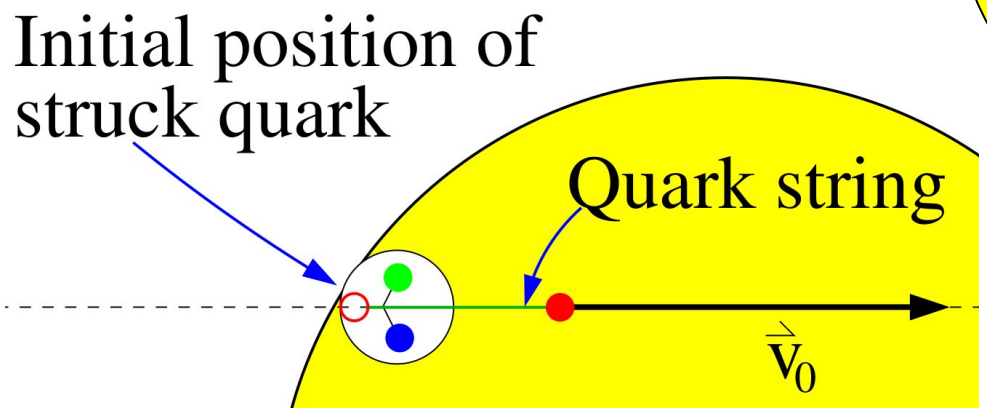

Does the quark escape? 46

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 $\vec{v}_o$ 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?

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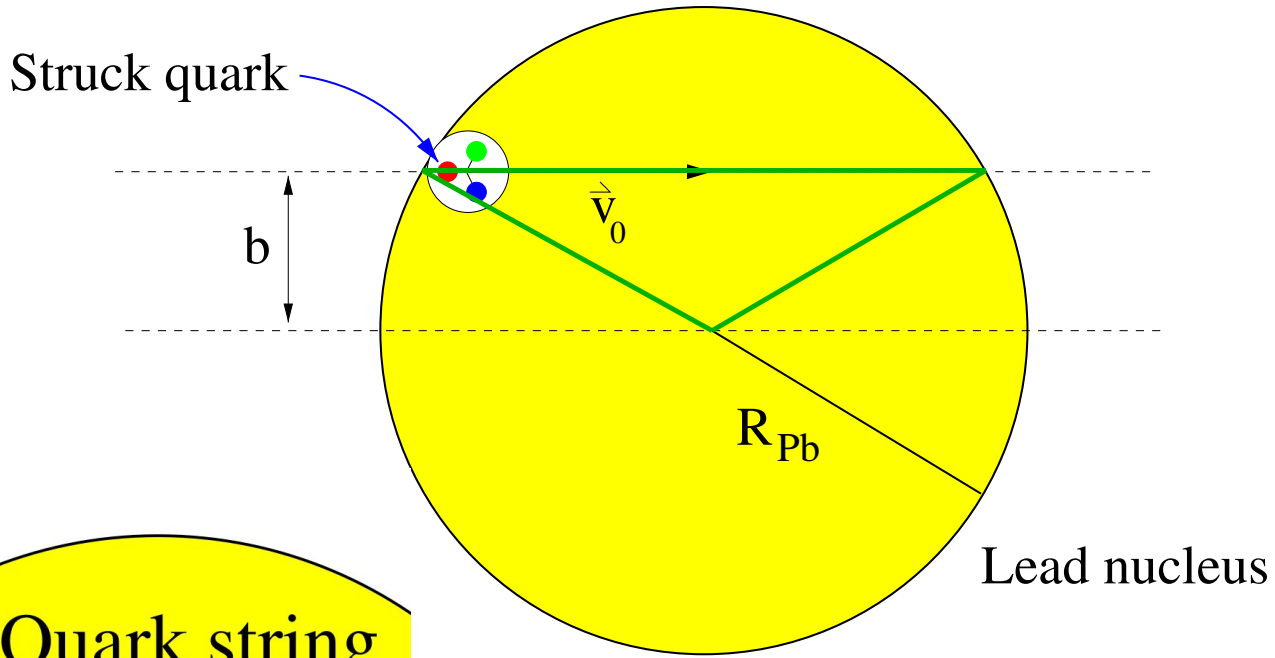

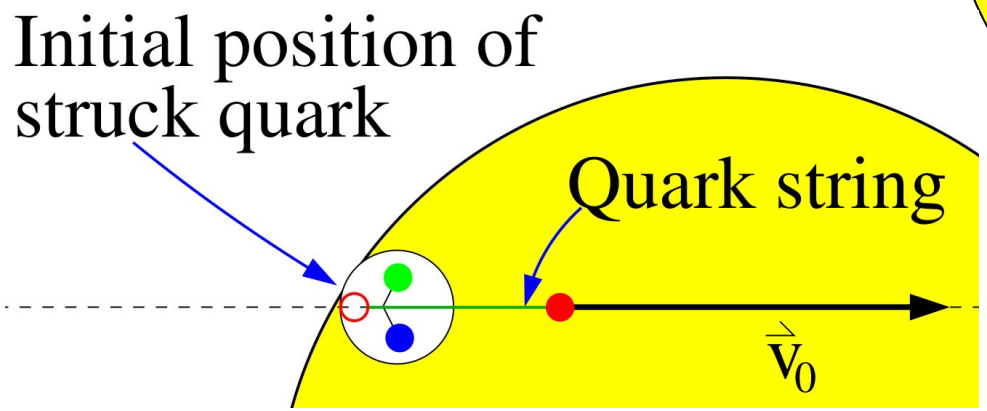

Does the quark escape? 47

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 $\vec{v}_o$ 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?

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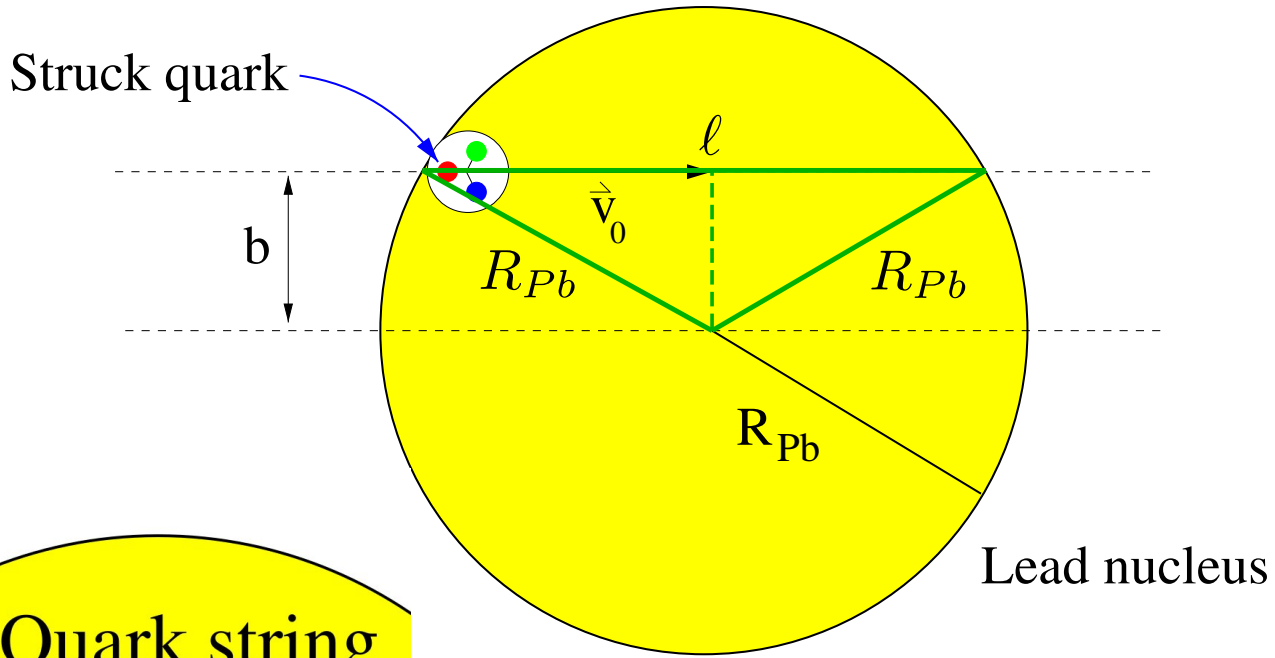

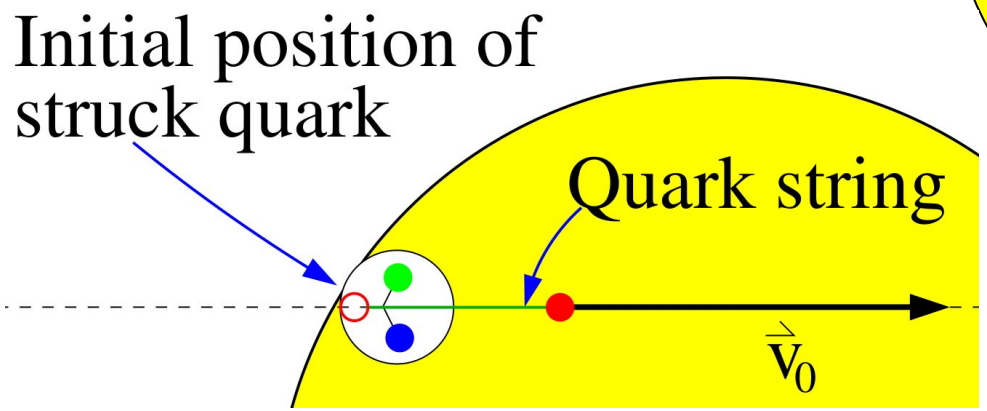

Does the quark escape? 48

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 $\vec{v}_o$ 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?

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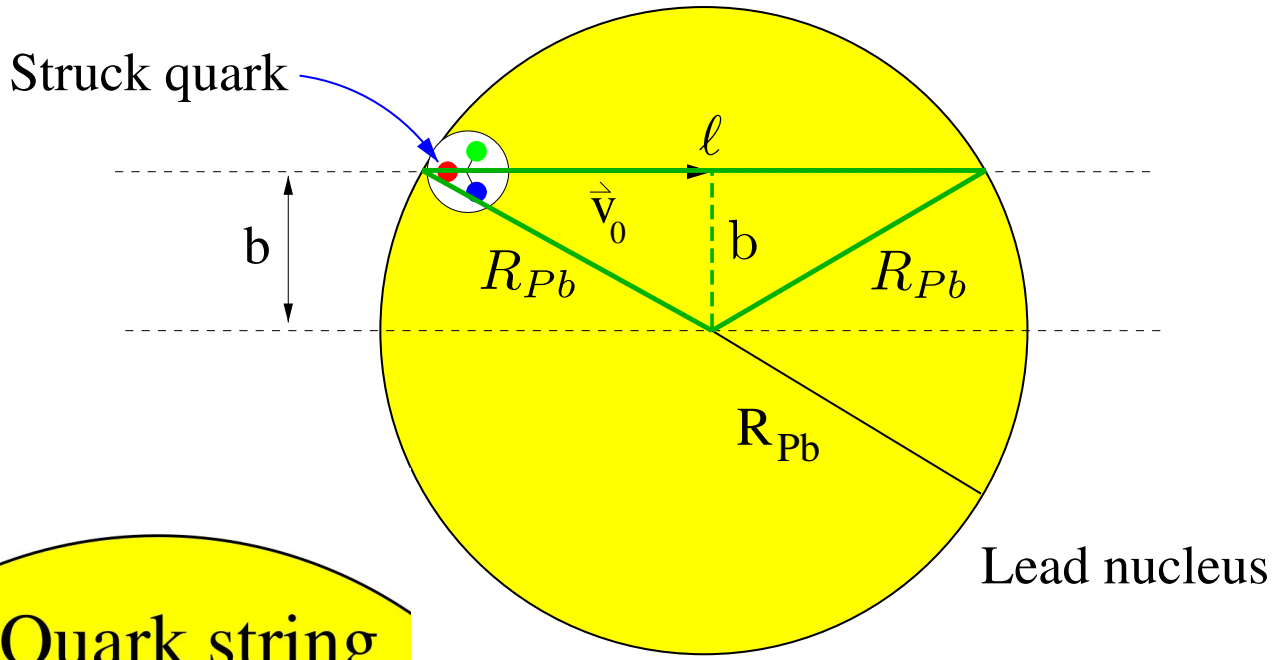

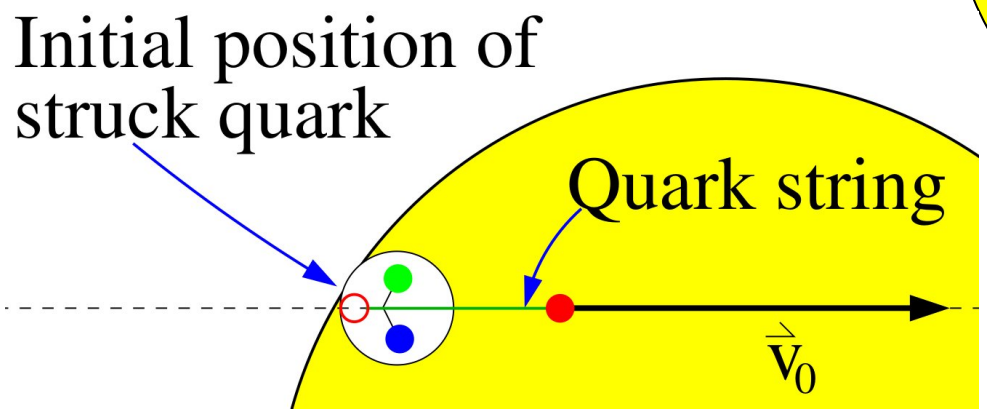

Does the quark escape? 49

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 $\vec{v}_o$ 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?

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