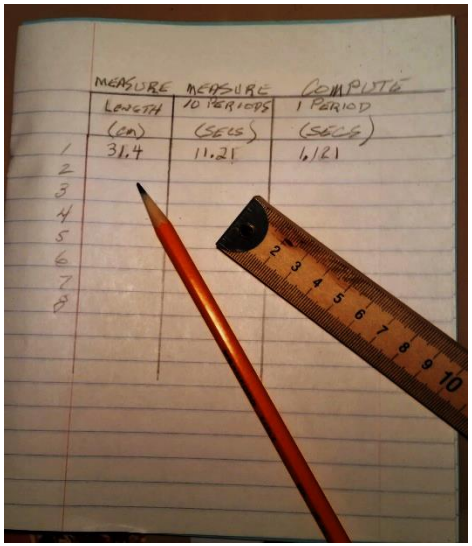
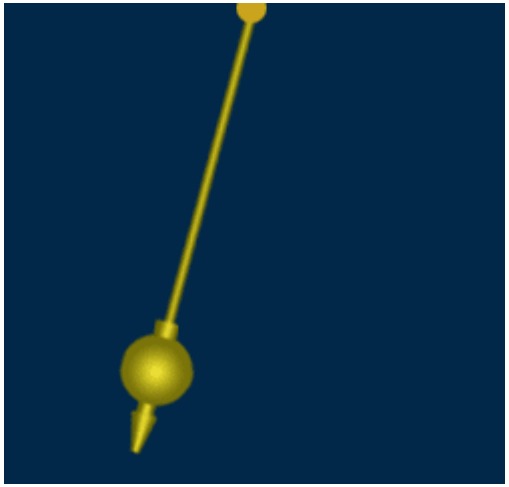
ARIZONA SCIENCE LAB

Oscillators and Waves

Using the Scientific Method





Institute Of Electrical And Electronic Engineers, Phoenix Section

Teacher In Service Program / Engineers In The Classroom (TISP/EIC)

"Helping Students Transfer What Is Learned In The Classroom To The World Beyond"

Our Sponsors

The AZ Science Lab is supported through very generous donations from corporations, non-profit organizations, and individuals, including:

Today's Science Workshop

- Today we will explore the scientific method through the physics of the pendulum, a simple oscillator, and then observe other oscillators and sound waves.
- The scientific method process:
  - ***Observe**, ask questions, make predictions;*
  - ***Plan** and conduct investigations, record data;*
  - ***Analyze** data, compare to predictions;*
  - ***Communicate** the results of investigations.*
- A procedure for exploring science!

Oscillators and Oscillations

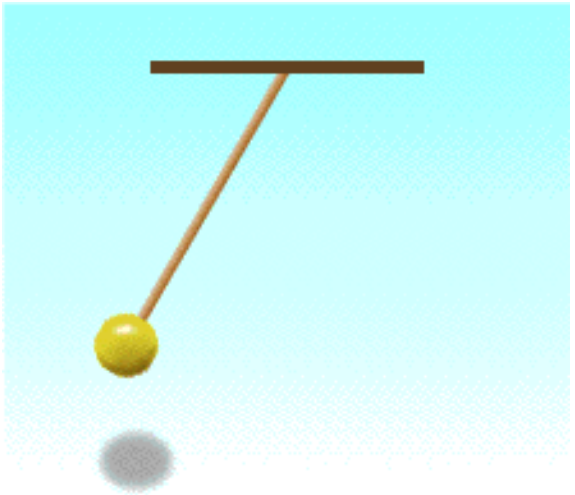
- Many objects in this world move in a back-and-forth or up-and-down motion.
- Oscillations or periodic behavior are very common in our lives:
  - Motion of a pendulum
  - Vibrations of strings on musical instruments
  - Suspension in a car going over a bump
  - Some oscillators generate **waves**
  - Sound, radio, and light waves

The Pendulum: Periodic Motion

Amplitude – the *displacement* from resting position.

Period of oscillation – time for one round-trip or one *cycle* (T seconds).

Frequency – number of cycles per second (Hz Hertz).



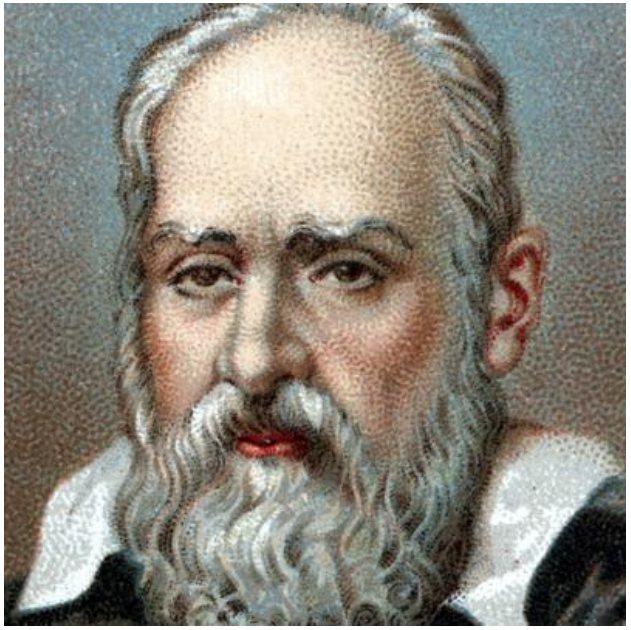
Observe: the *Pendulum* – A Simple *Oscillator*

Plan: Write down 3 hypotheses about the ***period*** of the pendulum

- The period depends on ***amplitude***
  - Accept? / Reject? (Galileo)
- The period depends on ***mass***
  - Accept? / Reject?
- The period depends on ***length***
  - Accept? / Reject?
- **Let's Find Out !!**

We Just Repeated Galileo's Experiment!

- 1602 – Galileo is 20 yrs old
- He's sitting in church in Pisa, Italy
- He's bored !!
- He sees a lamp swinging overhead
- He times the swings with his pulse
- Large swings or small, he observes *the period is always the same*!
- Fascinated, he later derives the: **law of the pendulum**



Plan and Analyze

- So … period depends on *length*, but *how* does it depend on length?
- Plan, make period measurements for different-length pendulums.
- Record the data in a table.
- Analyze our data, using graphs.

Lab Team Assignments

- Set and measure pendulum length
  - Top of string to center of washer
- Run the pendulum
  - Count the swings together, carefully
- Run the stopwatch
  - Start on ZERO! Stop on TEN!
- Record the data in your table
- Plot the data on your graph

Names: _____ Date: _____

My Pendulum Data

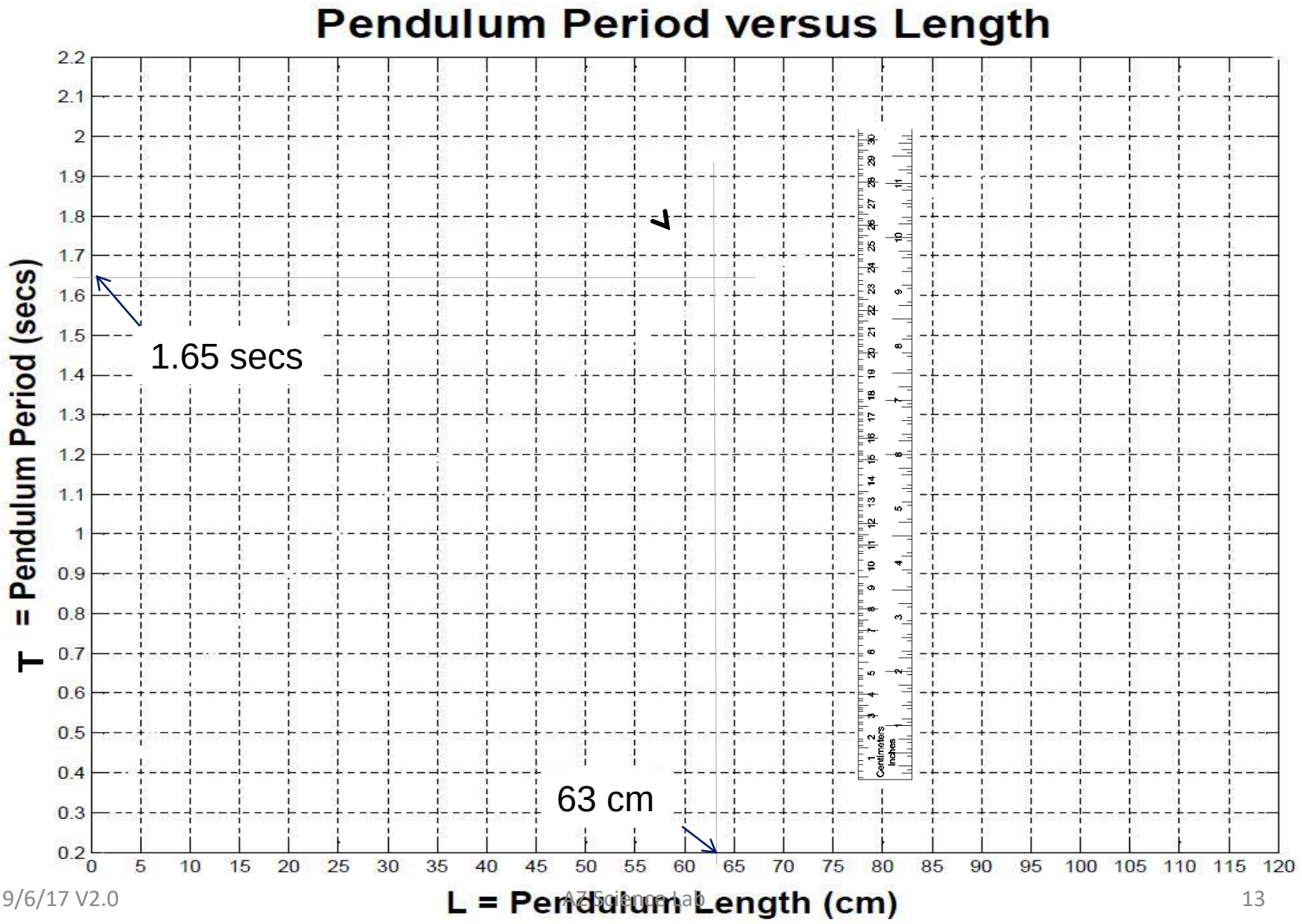
Choose lengths *no less* than 10.0 cm and *no greater* than 120.0 cm.

Compute the last column – just divide number in 2nd column by 10.

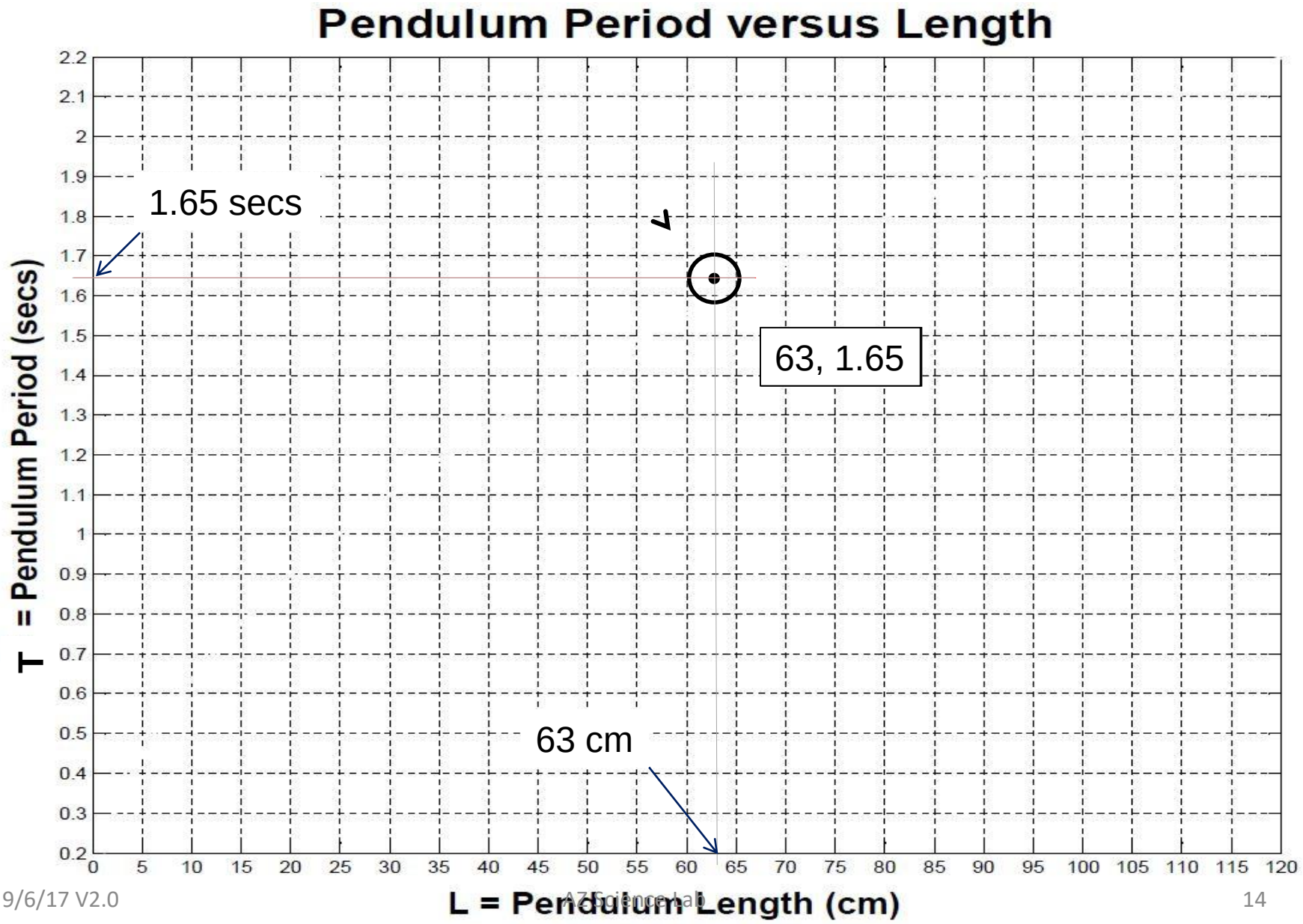
Spread lengths out evenly from 10 to 120 cm.

Measure ⬇	Measure ⬇	Compute ⬇
Length (cm)	**10 Periods (secs)**	**1 Period (secs)**
63	***16.5***	***1.65***

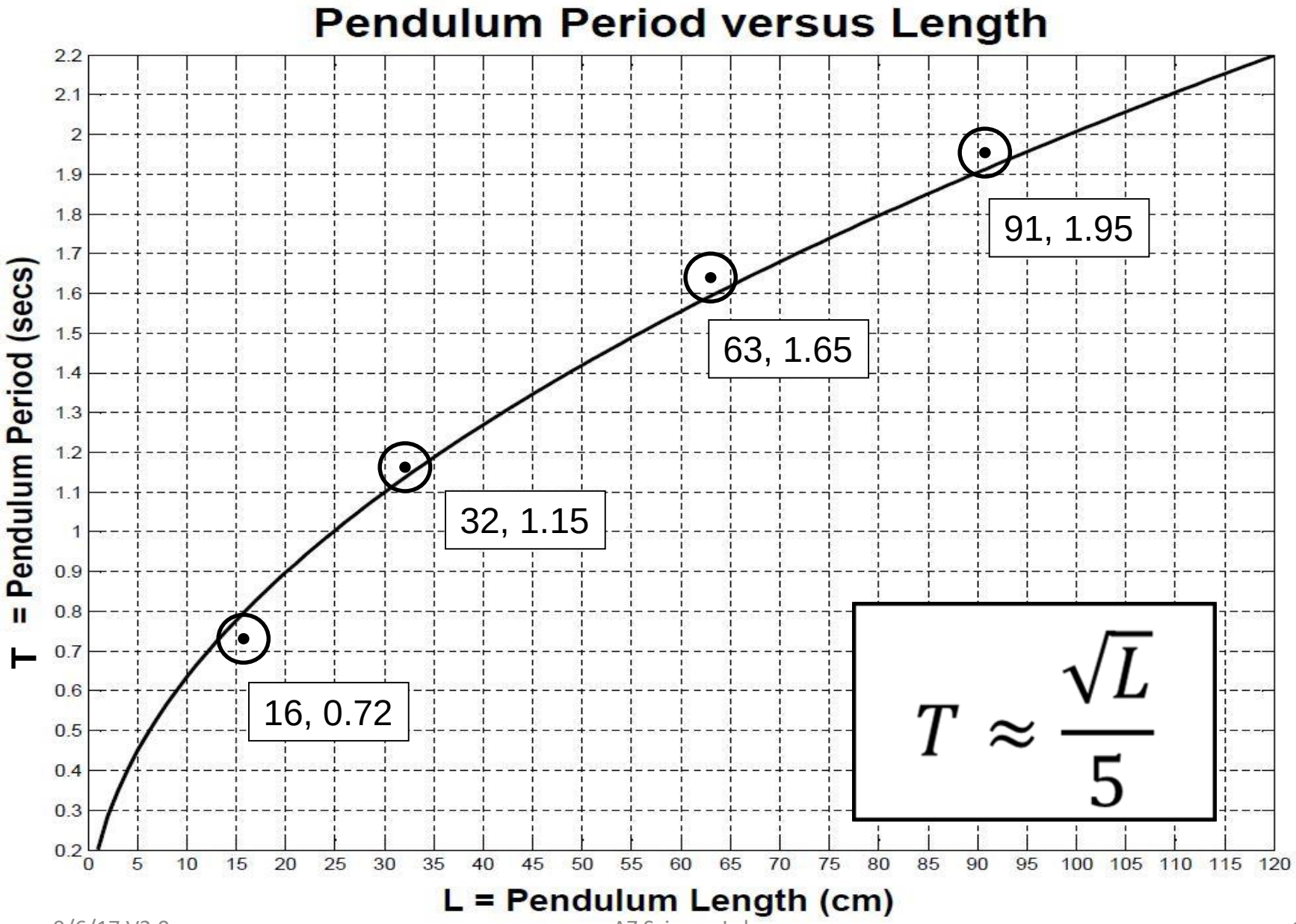
Graphing Your Data



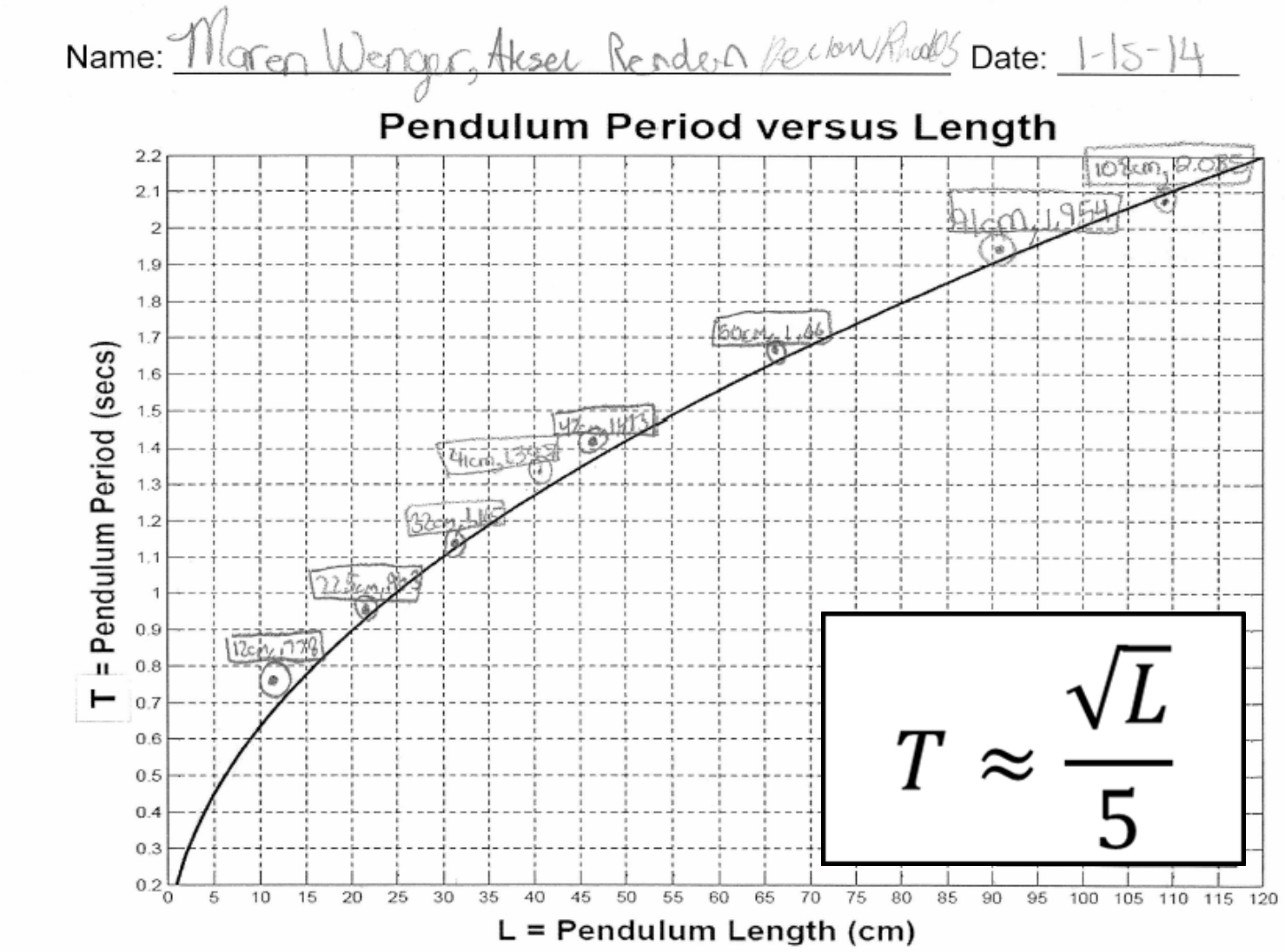
Graphing Your Data



Names: _____ Date: _____


Pendulum Period versus Length
T = Pendulum Period (secs)
L = Pendulum Length (cm)
16, 0.72
32, 1.15
63, 1.65
91, 1.95
$T \approx \frac{\sqrt{L}}{5}$

Compare Your Results to Galileo's



Quick Review of Oscillators

- Oscillators alternately *store* and *release* energy
  - For the pendulum, we can *see* the store/release cycle
  - ***Kinetic*** (motion) and ***potential*** (position) energy
- Oscillators can also create **WAVES:**
  - ***Audio*** waves, also called sound or ***acoustic*** waves.
  - ***Radio & Light*** waves, also called ***electromagnetic*** waves.

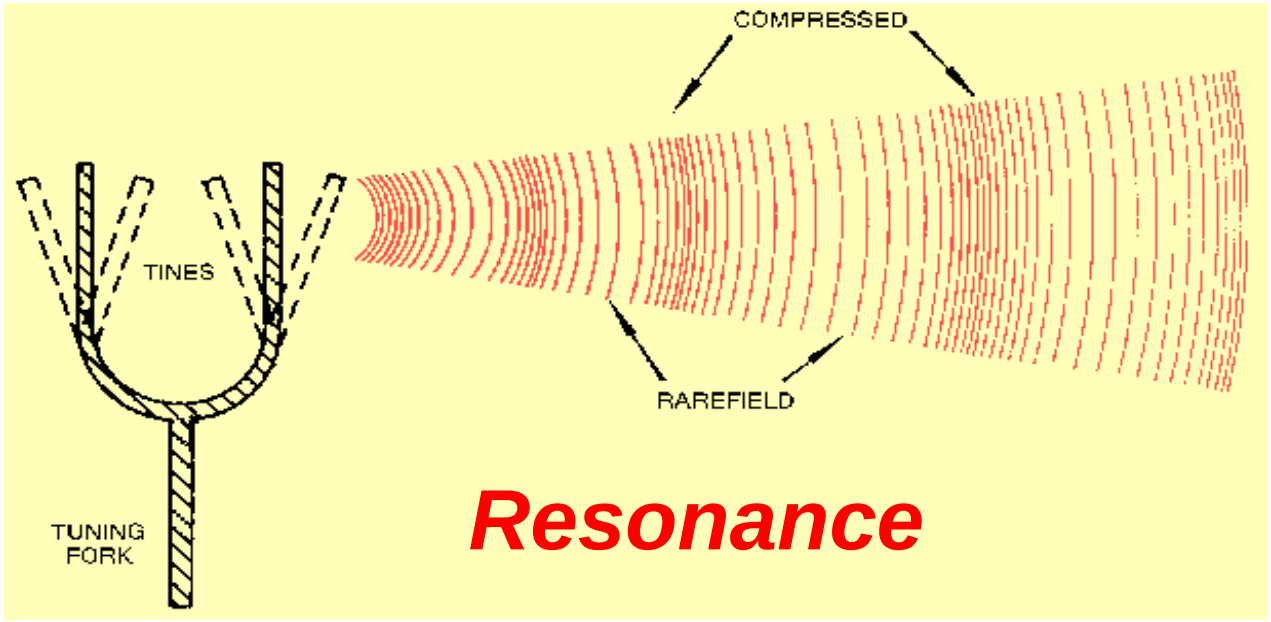
Waves

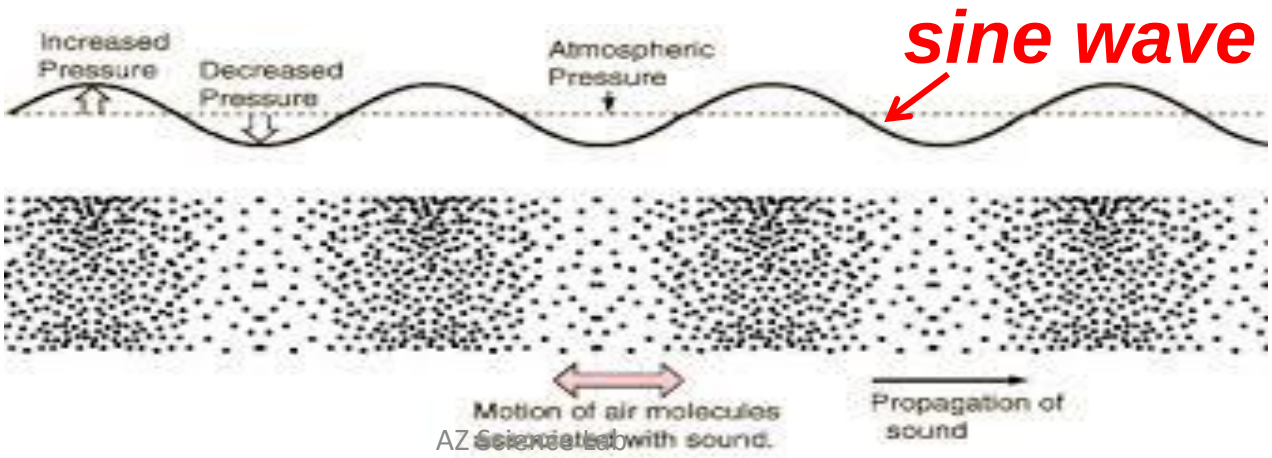
Waves are everywhere:

- Ocean: currents and tides of water.
- Sound: pressure vibrations in the air, hearing: pushing against the eardrum.
- Sight & light: light energizing the retina of the eye.
- Electromagnetic waves: radio, tv waves; can travel in a vacuum.

Tuning Fork Oscillator: Sound Waves

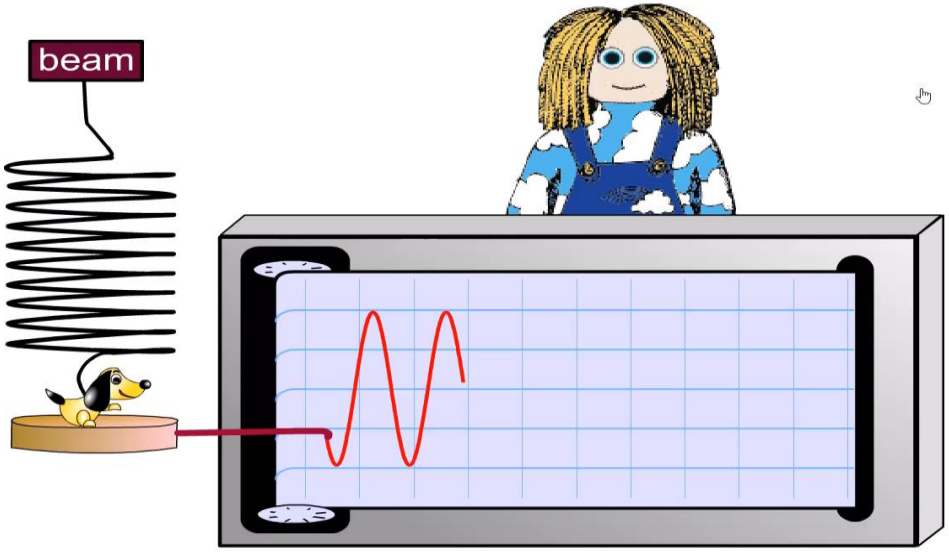
Period = .00391 secs Frequency = 1/.00391 = 256 Hertz



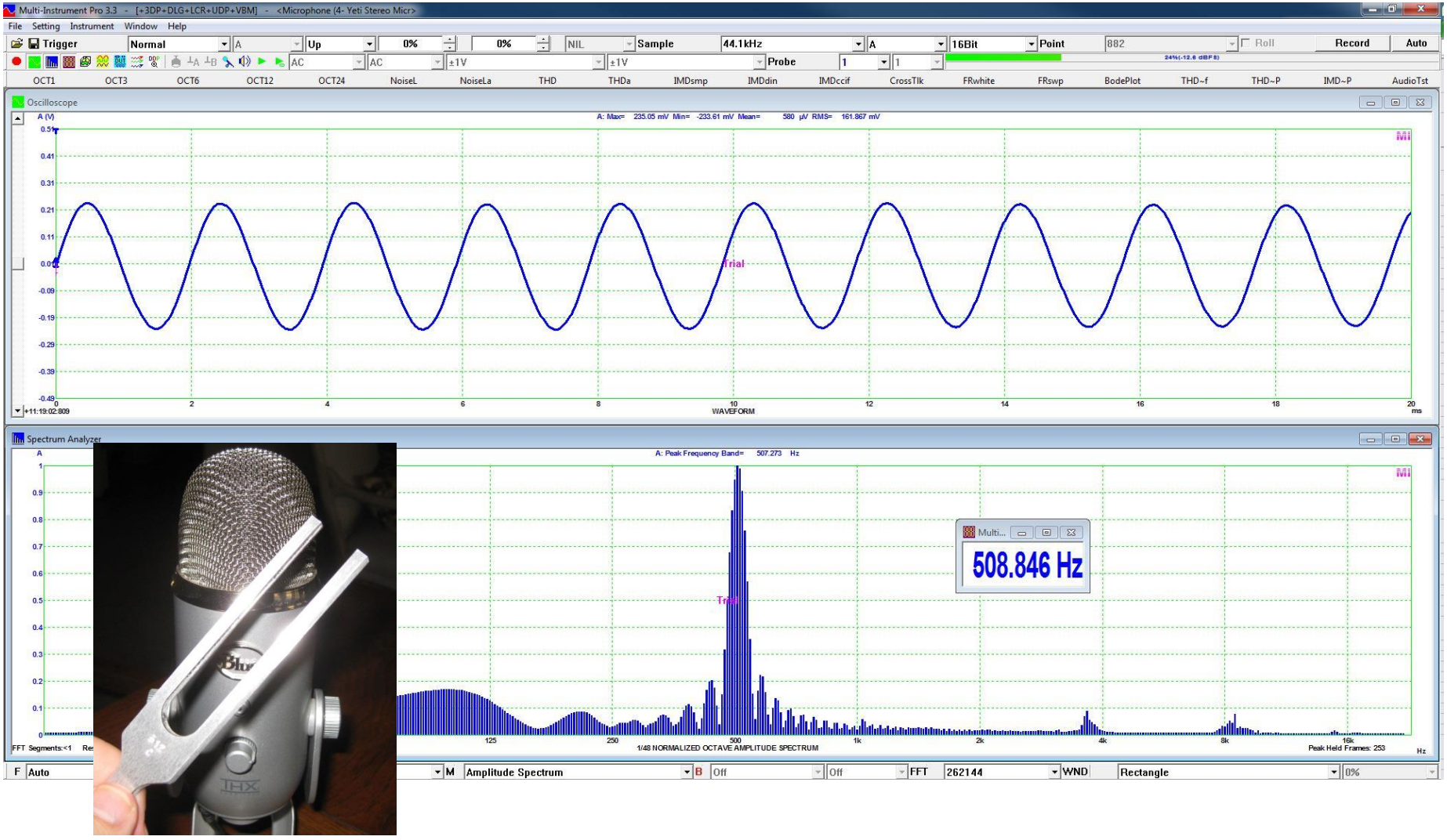


What is a “Sine Wave”?

- Common natural oscillating systems do not move at a constant rate
- A mass on a spring, for example, slows to a stop before again accelerating in the opposite direction
- Over time, such motion traces out a waveform called a sinusoid or “sine wave” for short



Making and “Seeing” Audio (Sound) Waves
Oscilloscope and *Spectrum Analyzer*



Wine Glass Audio Oscillator

Resonance Breaks a Wine Glass !

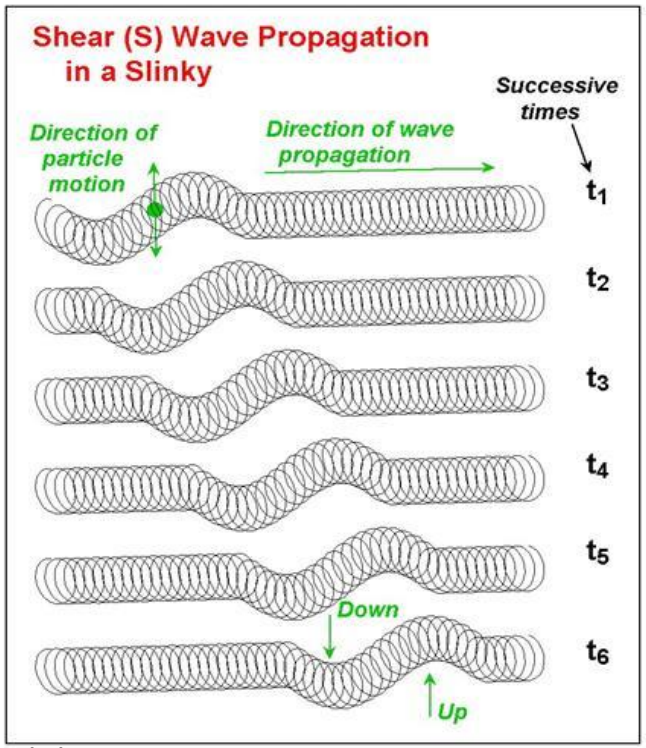
Music on Beer Bottles

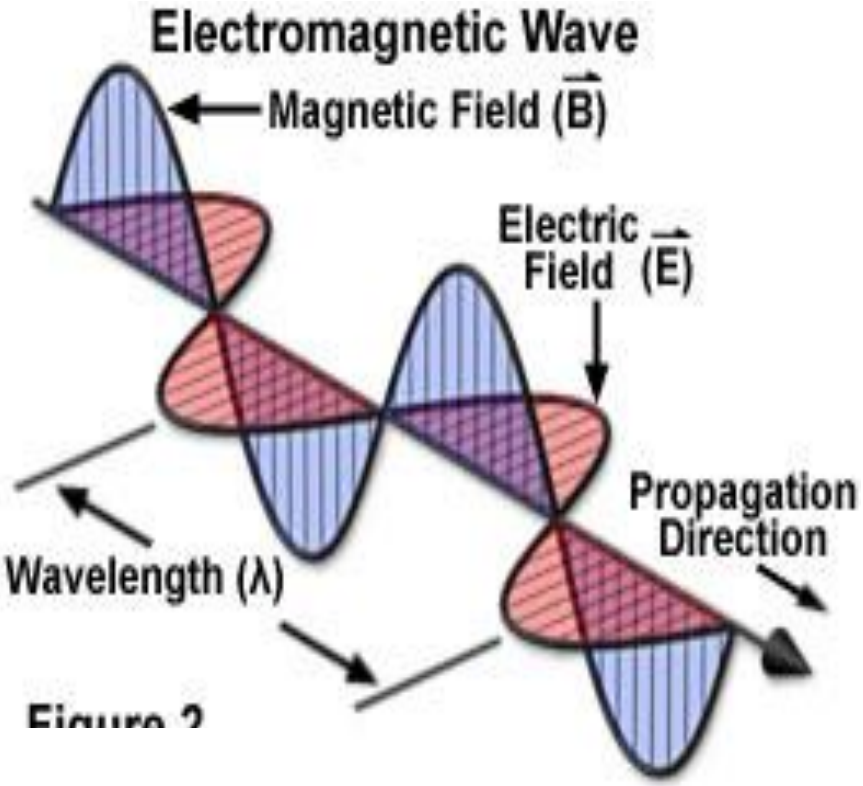
Coke Bottle Oscillator - What Makes It Work?

Why Oscillators Matter
Tacoma Narrows Bridge Failure!!

Electromagnetic Waves: Radio and Light

Slinky Demo
Electrons on a Wire Antenna





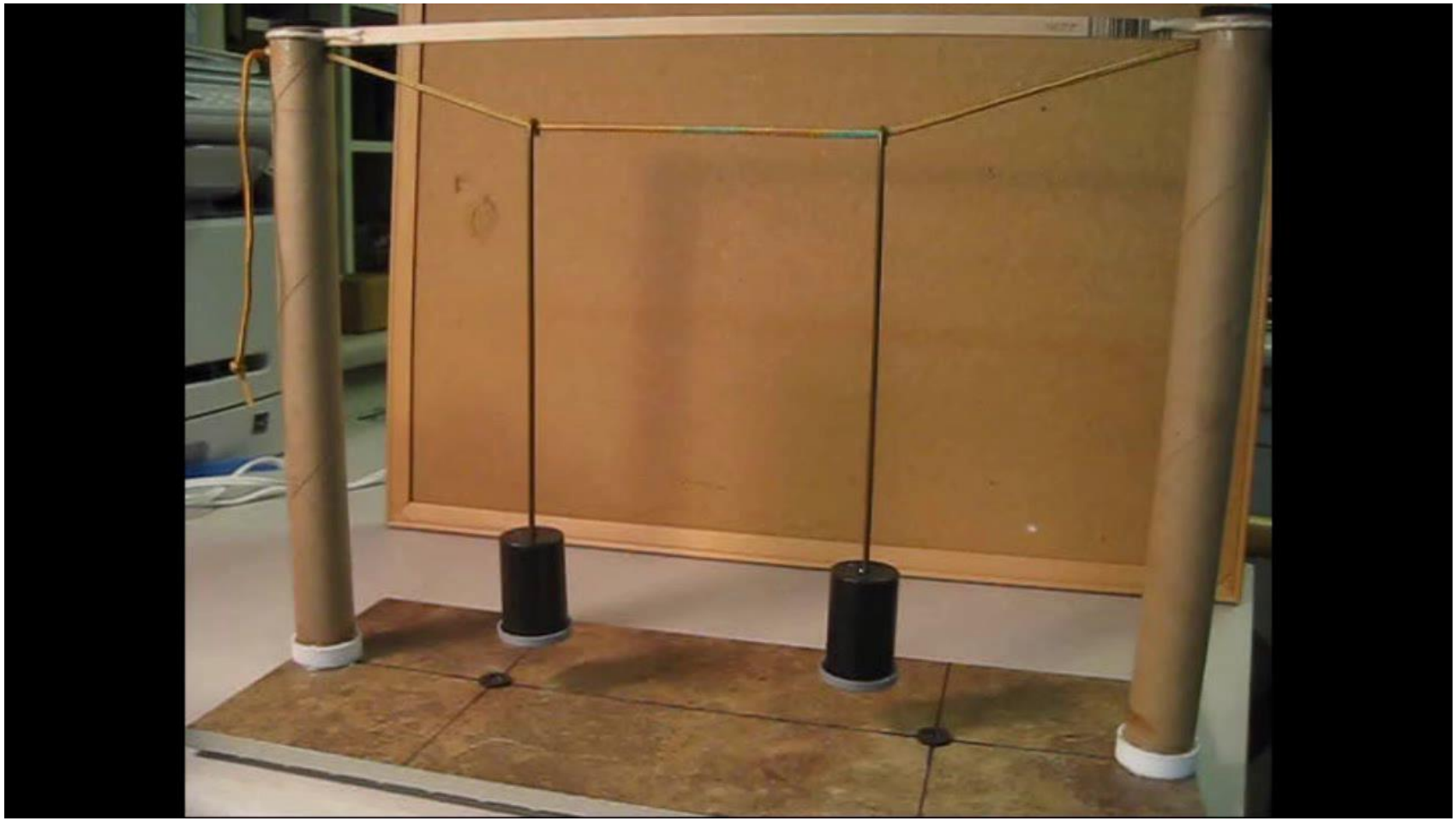
What Have We Studied?

- How to apply the **Scientific Method:**
  - **Observe, Plan, Analyze, Communicate (OPAC)**
  - **Hypotheses:** *accept* or *reject* based on experiment!
- Practical **measurements** of time and length:
  - Data recording and graphing
  - Comparing **measured** results to **theory**
- **Reporting** of results.
- Oscillators make waves!
  - Acoustic (Sound), Electromagnetic (Radio, Light)

Science Vocabulary

- *Hypothesis*
- *Pendulums, Oscillators*
- *Kinetic*, *Potential* energy
- *Oscillator Period* & *Frequency*
- *Resonance*
- *Waves* – *Acoustic* (sound)
- *Waves* – *Electromagnetic* (radio, light)

Final Exam: What Do You See? Why Might This be Happening?



Make Your Own Straw “Oboe”

Careers in STEM

- You must find your passion
- You can have a very rewarding career in science and engineering:
  - Financial, satisfaction, enjoyment
- Need learning and training (education)
- Maybe you will even become an engineer or scientist!

Careers in STEM

Have Fun Today?

Check out our website: www.azsciencelab.org
click on the “For Students” tab!

Thanks for coming and exploring with us
the scientific method, oscillators, and waves!

Paper Forms

Compute L using T

- Using Galileo's Formula we can solve for either T or L given the other:

$$T \approx \frac{\sqrt{L}}{5}$$

L = ??

Using a Heuristic

- A **heuristic** is any approach to problem solving using a practical method not guaranteed to be perfect, but sufficient for the immediate goals.
- Where finding an optimal solution is impossible or impractical, heuristic methods can be used to speed up the process of finding a satisfactory solution.
- Heuristics can be mental shortcuts that help making a decision easier. Examples include using a rule of thumb, an educated guess, an intuitive judgment, or common sense.

Name: _____ Date: _____

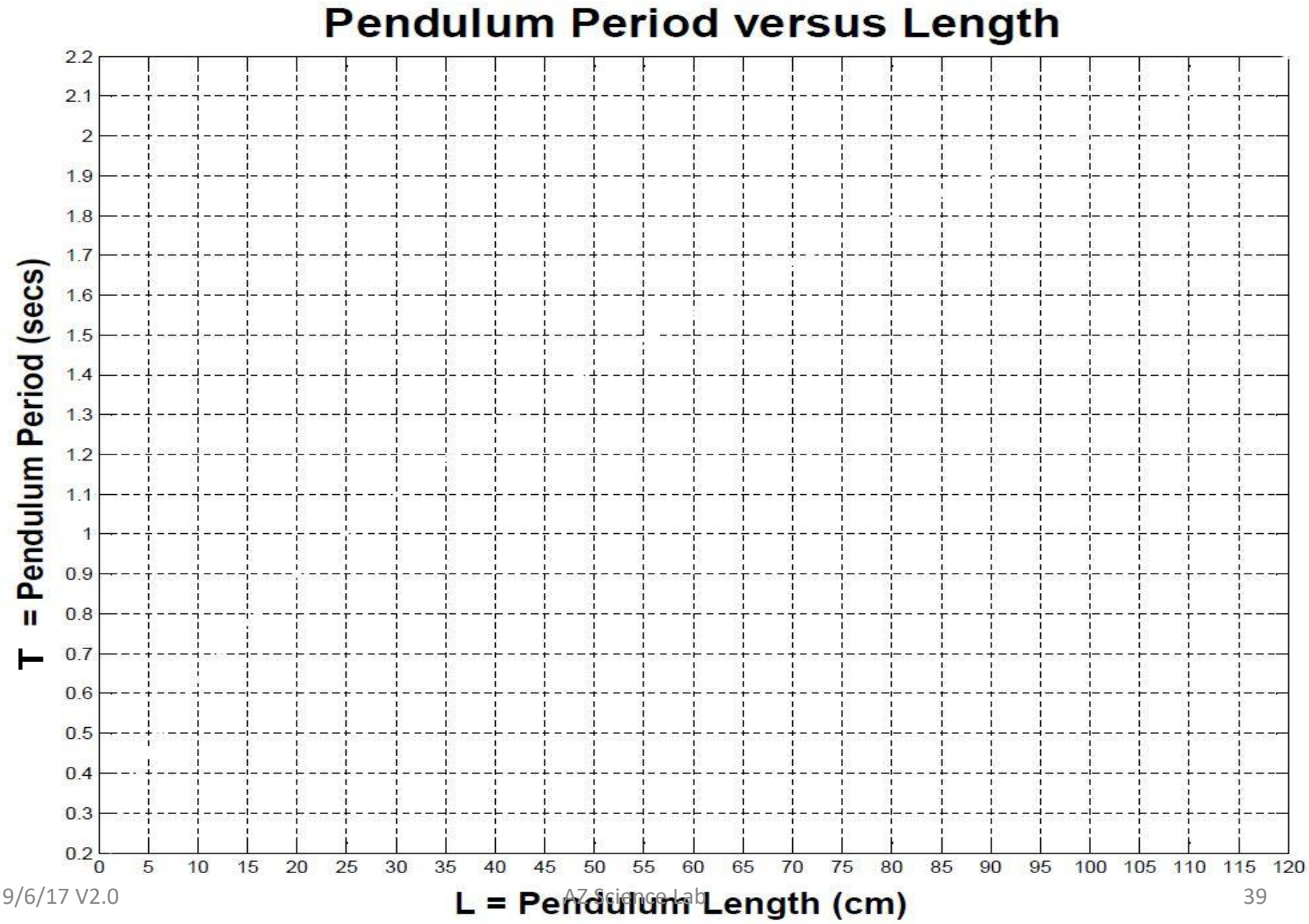
My Pendulum Data

Choose lengths *no less* than 10.0 cm and *no greater* than 120.0 cm.

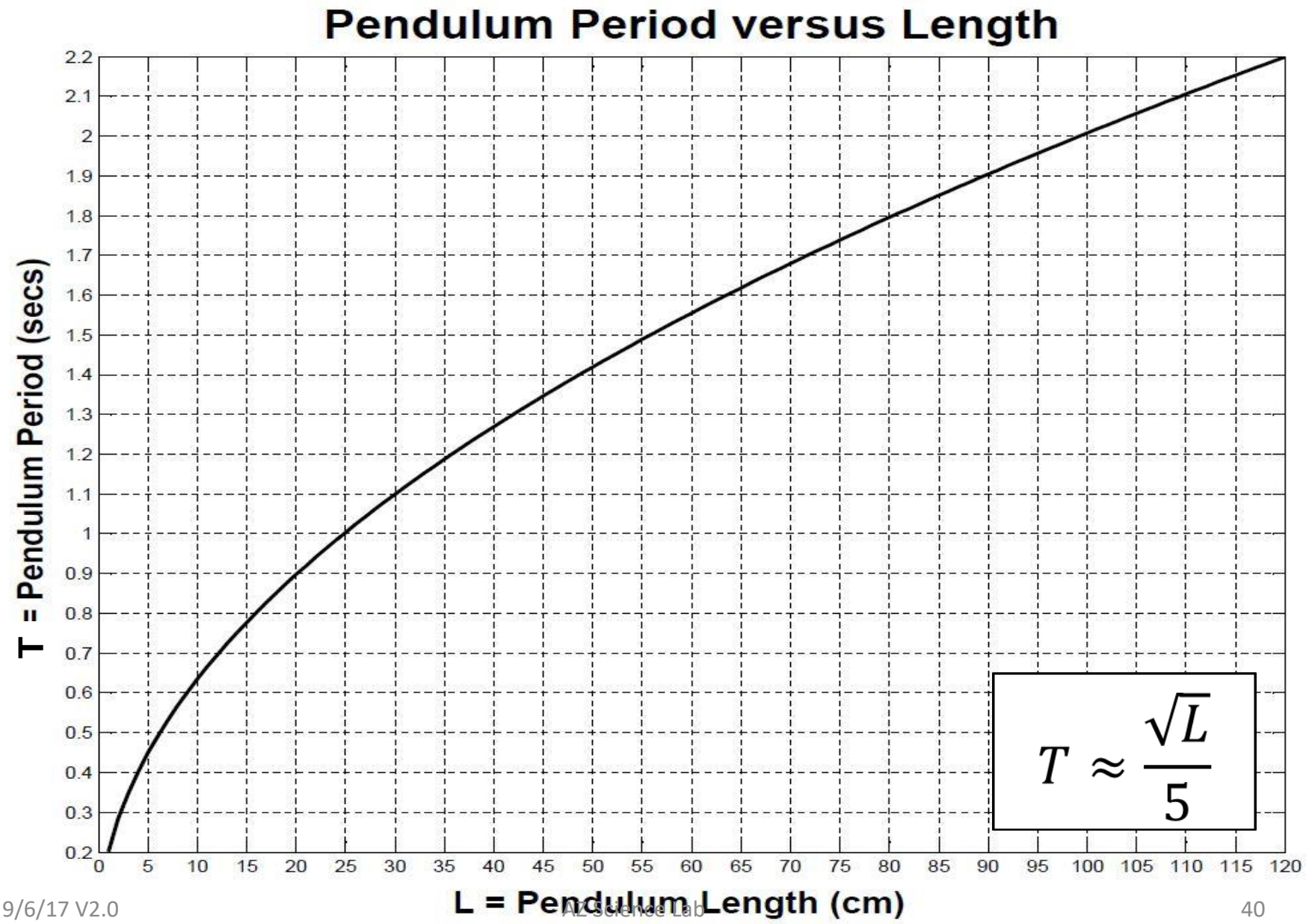
<u>Compute</u> the last column – just divide number in 2nd column by 10.

Measure ↓	Measure ↓	Compute ↓
Length (cm)	**10 Periods (secs)**	**1 Period (secs)**

Names: _____ Date: _____


Pendulum Period versus Length
T = Pendulum Period (secs)
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
L = Pendulum Length (cm)

Name: _____ Date: _____


Pendulum Period versus Length
T = Pendulum Period (secs)
L = Pendulum Length (cm)
$T \approx \frac{\sqrt{L}}{5}$

Math Formula for Pendulum Period

T (secs) versus L (cm)

$$T = 2\pi\sqrt{L/g}$$

$$\pi = 3.1416 \ \ldots$$
$$g = 980.66\ cm/sec^2$$

Good Approximation:

$$T \approx \frac{\sqrt{L}}{5}$$

Graph the Table Results

- Communicate your results:
  - Graph the first (length) column against the last (time or period) column.
  - Vertical axis is time (T) in seconds
  - Horizontal axis is pendulum length (L) in cm.

- Compare your results to Galileo's!

Properties of Waves

- **Energy:** waves transfer energy from one place to another.
- **Momentum:** when a wave is absorbed or reflected by an object, the wave pushes on that object.
- **Velocity:** it takes time for a wave to travel from one place to another –
  - Light: 186,000 miles/sec, 300,000 km/sec.
  - Sound: (in air) about 1129 ft/sec.