Teaching Modern Physics for middle & High School Students

Jongwon Park

(Chonnam National University)

Why modern physics
for middle/high school students?

1. Relativity and basic ideas of quantum mechanics are already about 100 years old
   → modern physics is not 'modern'

2. Modern society is already applied with modern physics
   → GPS, Satellite, All electronics, Movie, …

Why modern physics for middle/high school students?

3. Students want to learn modem physics in their physics class.

- Modern Physics: relativity, black and white holes, the Higgs particle, quantum physics, expanding universe, time machine, …
- Modern Chemistry: quark, observing electron microscope, developing new drugs, fuel cell, …
- Modern Biology: genetic engineering, stem cells, viruses, the brain, cancer, bio-energy, endocrine disruptors, …
- Modern Earth science: future of the earth, planets similar to the earth, new technologies for resolving greenhouse effect, alien life, …
- High Technology: alternative energies, computers, new vehicles, new inventions, science in movies, robots, …

Basic difficulty
in teaching modern physics to students

Physics has strict hierarchical structure

→ High level concept (modern physics) cannot be understood
without understanding lower concept of physics

→ MHSS cannot have opportunity to learn modern physics
because there are too many basic necessary concepts
that should be learned before learning modern physics

Assumption for teaching modern physics for middle/high school students (MHSS)

We need alternative assumption to teach modern physics to SHSS

Assumption:

Modern physics can be taught to SHSS
by making modern physics be familiar to students

→MHSS can learn modern physics
if they can feel familiarity about modern physics
without an accurate understanding of the modern physics

Example related to the assumption: The rotation of the Earth

All of students, even some elementary students, say that " I know that the Earth rotates"

→ How do they know that knowledge?

→answer: The students 'know' the knowledge by becoming familiar with that knowledge

They did not discover the rotation of the Earth through experiment.

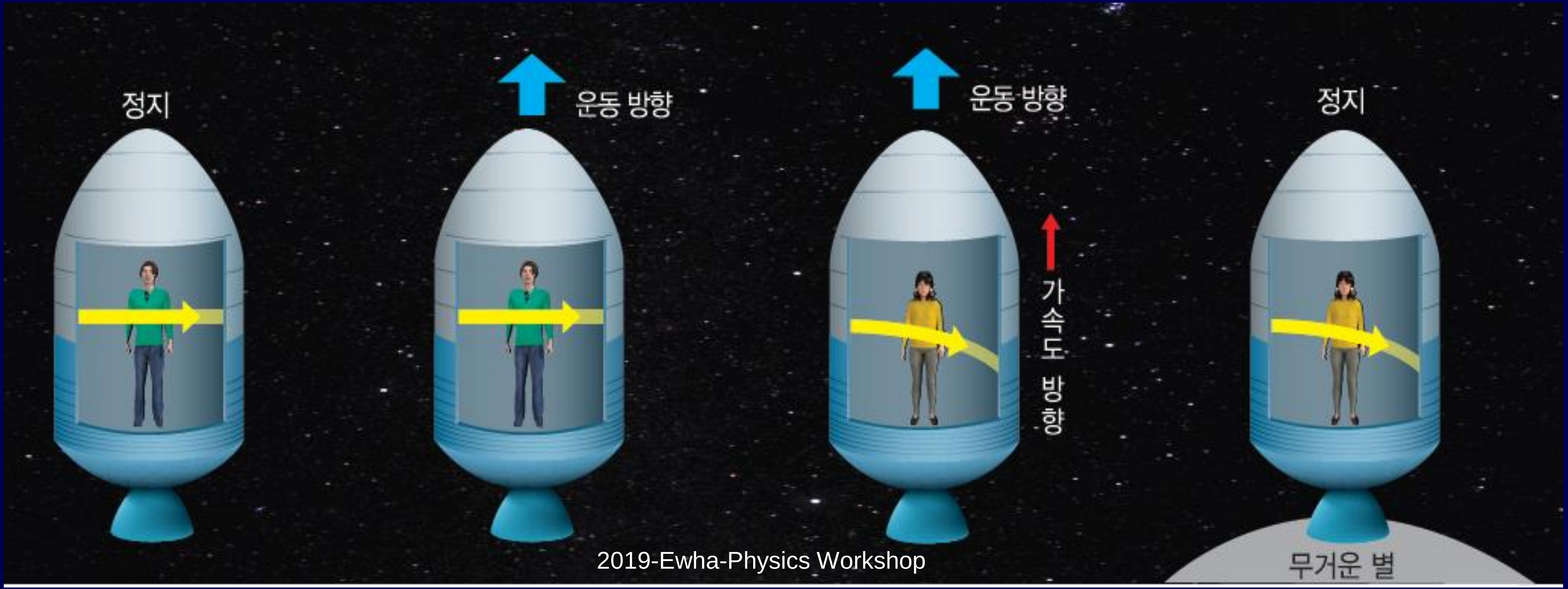
They did not observe the rotation of the Earth directly.

They cannot feel that the Earth rotates.

They cannot give an answer if we ask "If the Earth rotates, why do not feel dizzy?, why does an object fall vertically when you drop it? …"

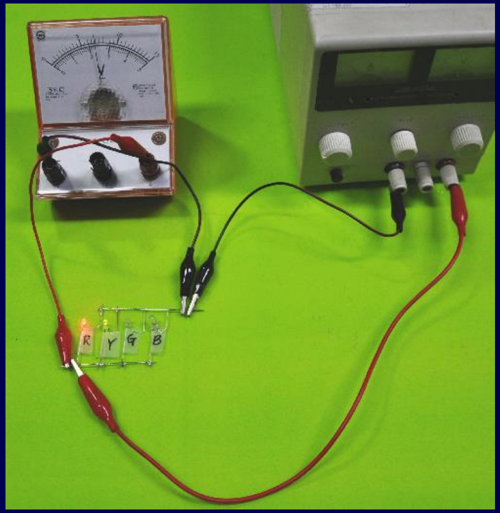
First strategy:
use of simple exp. demo, analogy, simple explanation

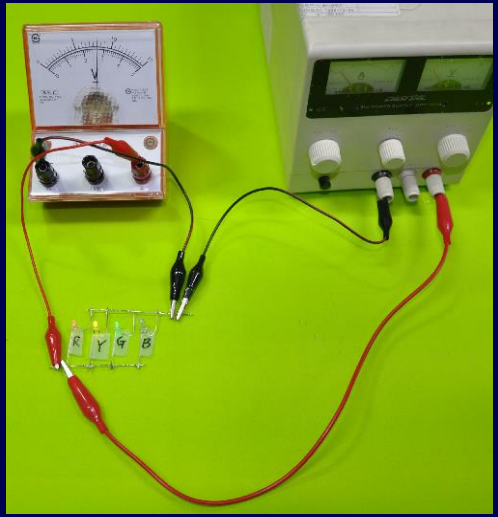
→Special and general relativity are introduced to MHHS
using simple though experiments

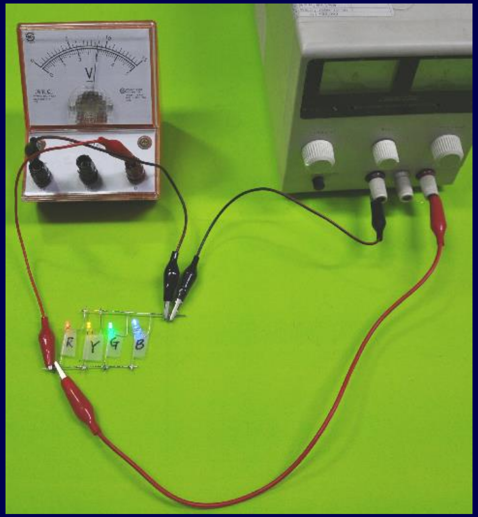


First strategy:
use of simple exp. demo, analogy, simple explanation

Measuring Plank constant using LEDs : E=eV=hf







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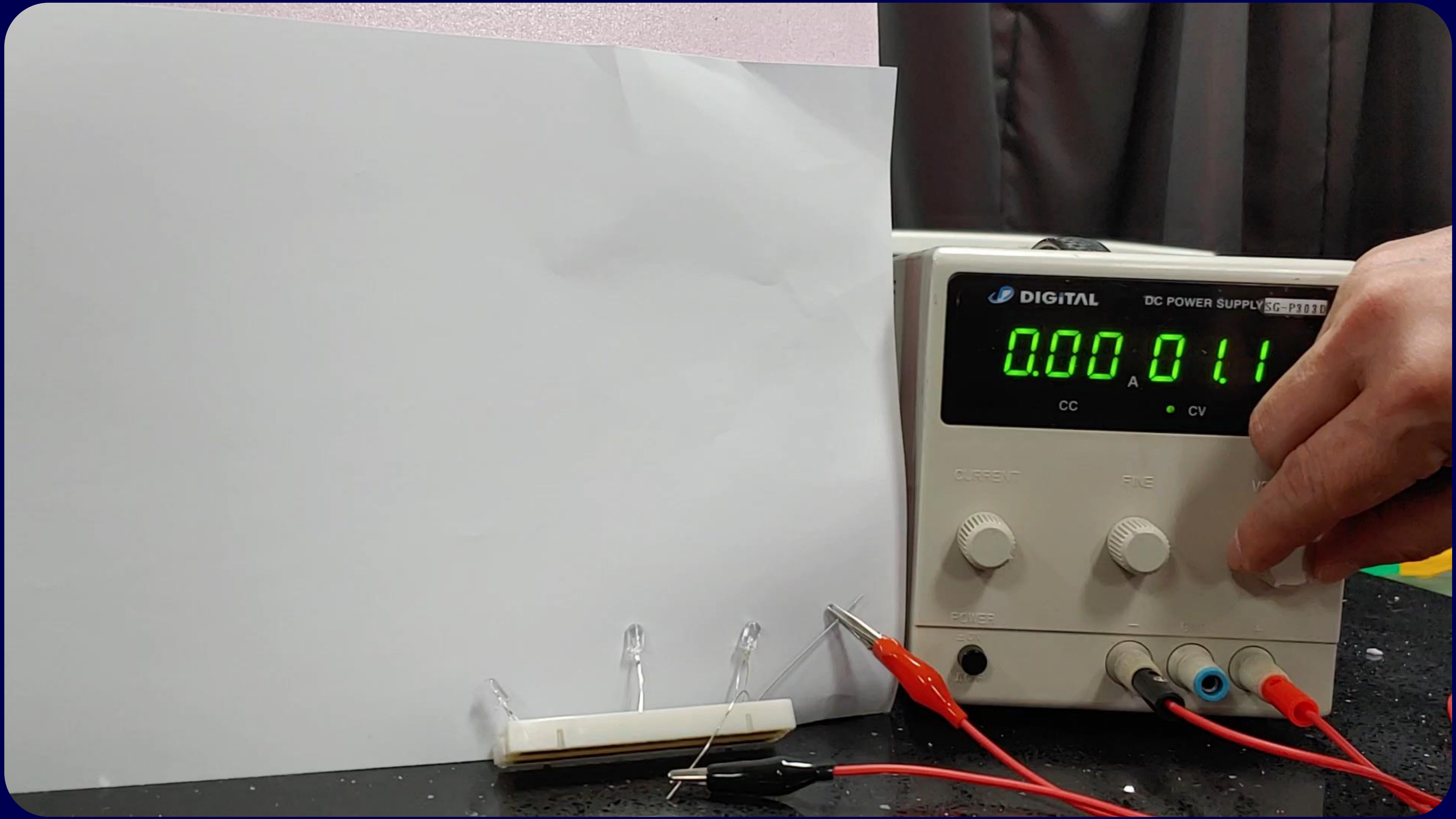

First strategy:
use of simple exp. demo, analogy, simple explanation

Measuring Plank constant using LEDs : E=eV=hf

$h=6.62607004\times10^{-34}$ (J·s) = $4.135667662\times10^{-15}$ (eV·s)

	LED				Average
Color	Red	Yellow	Grene	Blue	
Wavelength(nm)	660	590	525	450	
Voltage(V)	1.70	2.05	2.65	2.80	
Plank constant(h)	3.74×10^{-15}	4.03×10^{-15}	4.63×10^{-15}	4.20×10^{-15}	4.15×10^{-15}

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Observing photo-electric effect : Photo-Voltaic effect using copper plates

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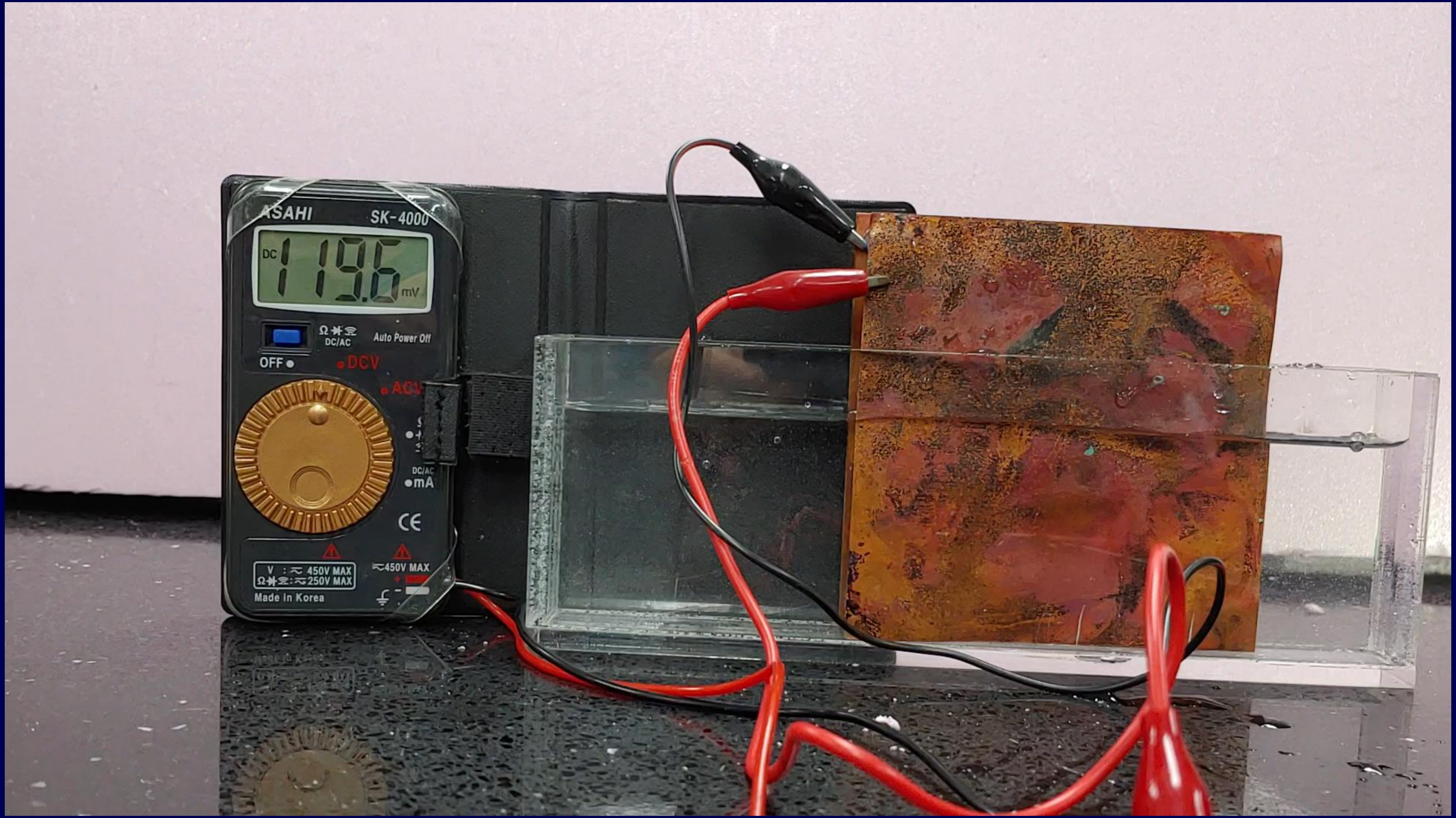

First strategy:
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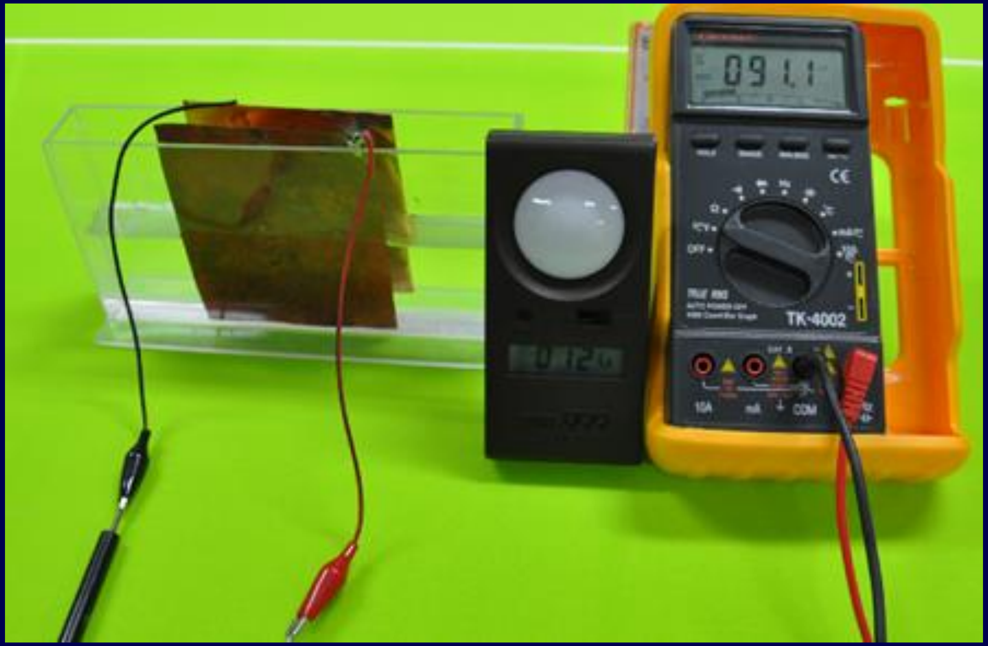
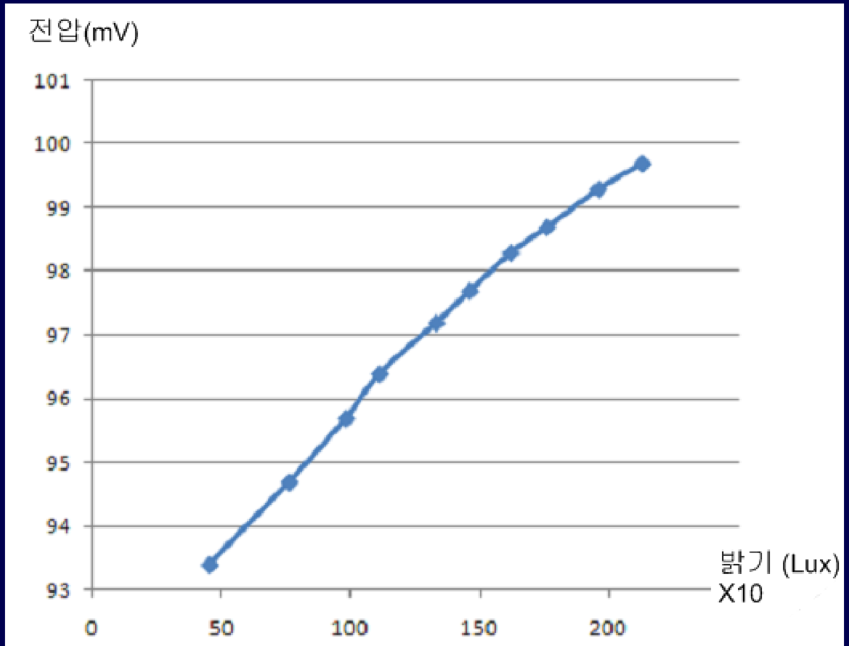
Observing photo-electric effect : Photo-Voltaic effect using copper plates

Voltage(mV)	93.4	94.7	95.7	96.4	97.2	97.7	98.3	98.7	99.3	99.7
Brightness(Lux)	750	760	980	1110	1330	1460	1620	1760	1960	2130





First strategy:
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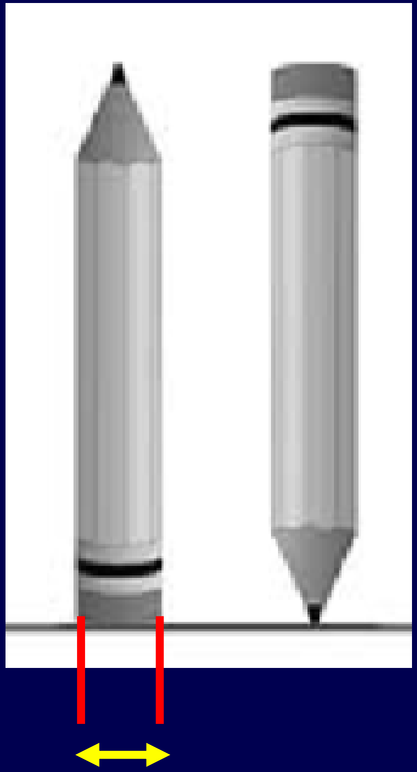
Uncertainty principle : analogy of pencil



Δx

Left pencil → location is unclear, but $\Delta P = 0$

Right pencil → location is exact, but $\Delta P \neq 0$

First strategy:
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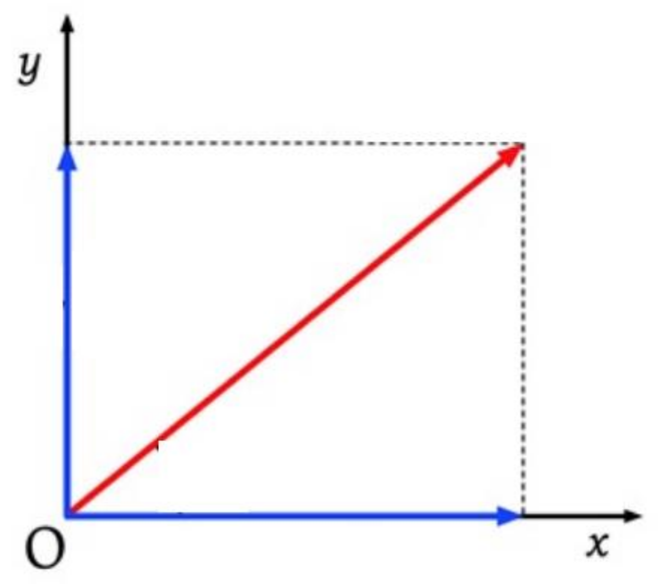
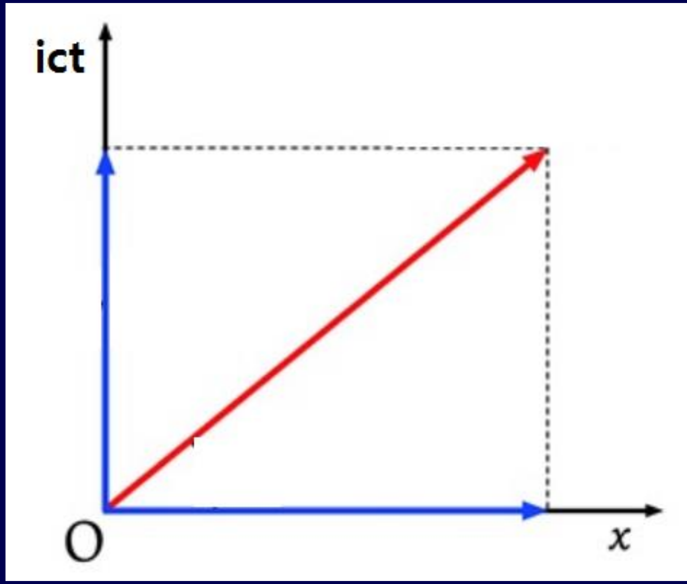
4 dim. Space-time: shadow on space axis and shadow on time axis





→ Change of time, change of length are so natural, trivial.

First strategy:
use of simple exp. demo, analogy, simple explanation

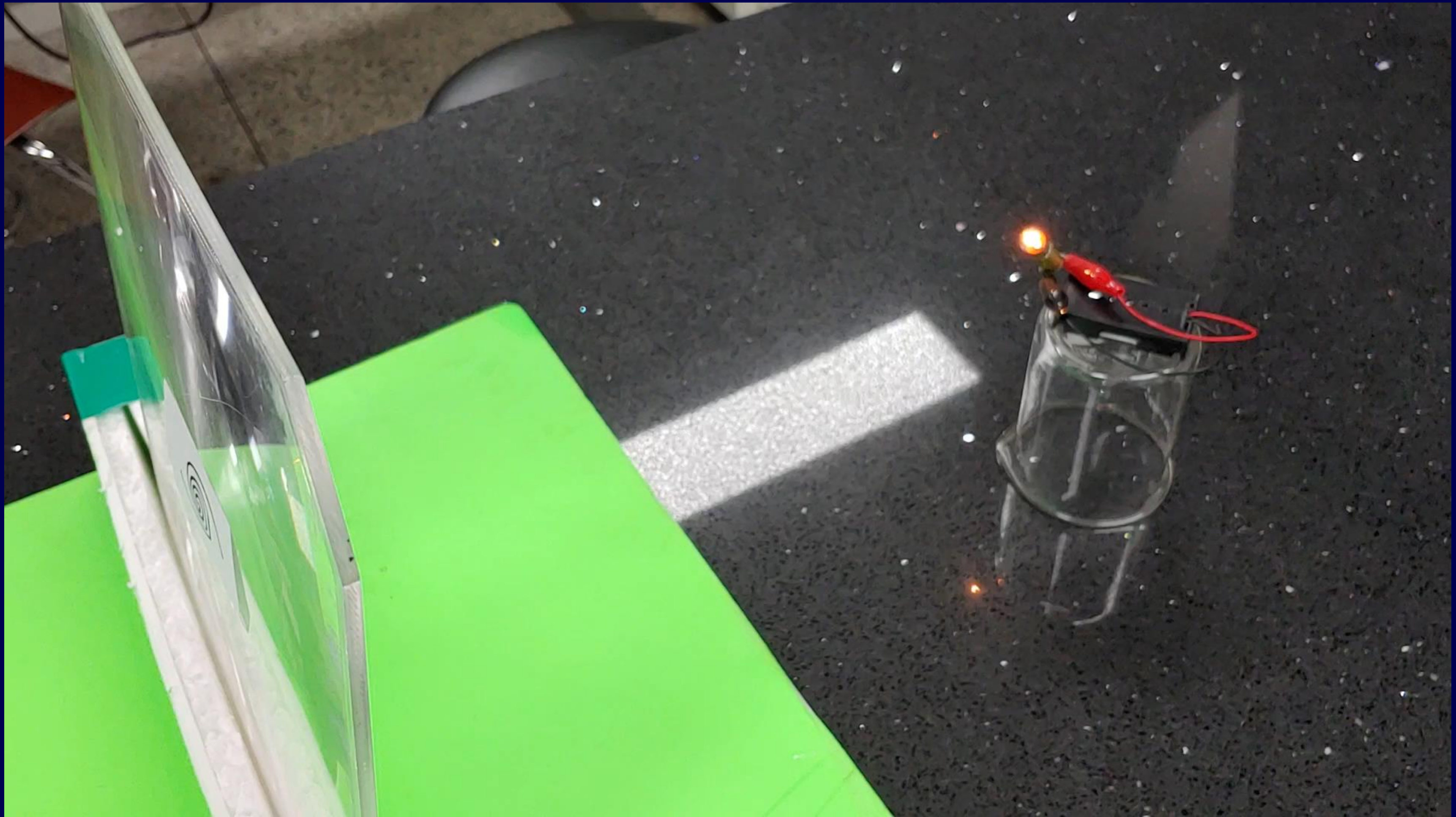
Curved light in general relativity: laser light in the sugar water

(thin sugar) water

Dense sugar water

First strategy:
use of simple exp. demo, analogy, simple explanation

Gravitational lens: small lamp & large convex lens



First strategy:
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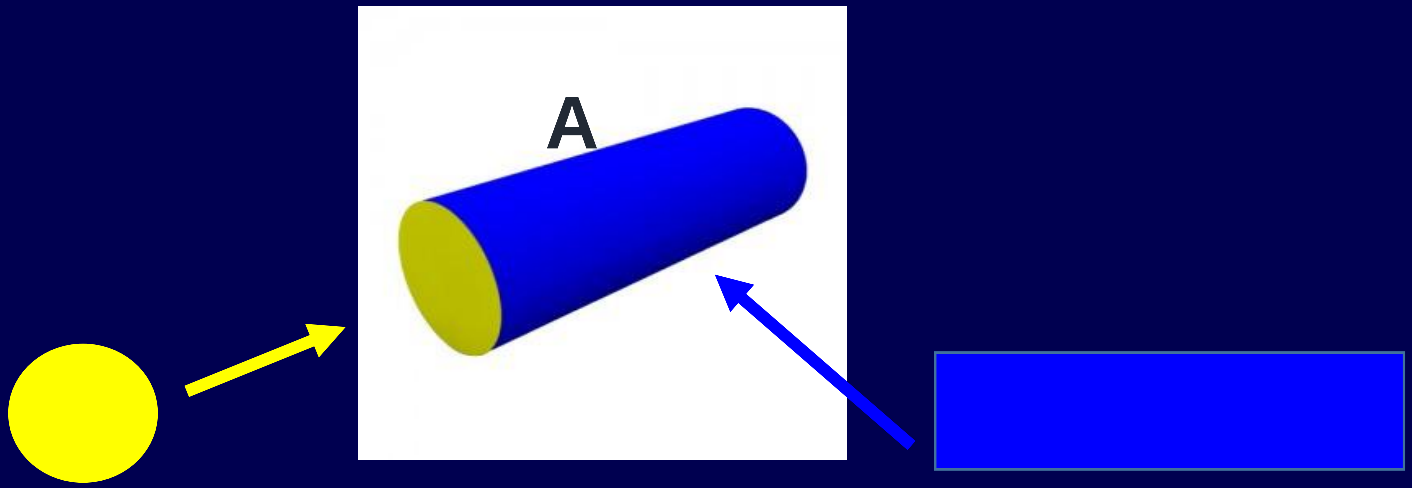
Particle-wave duality : observation of cylinder

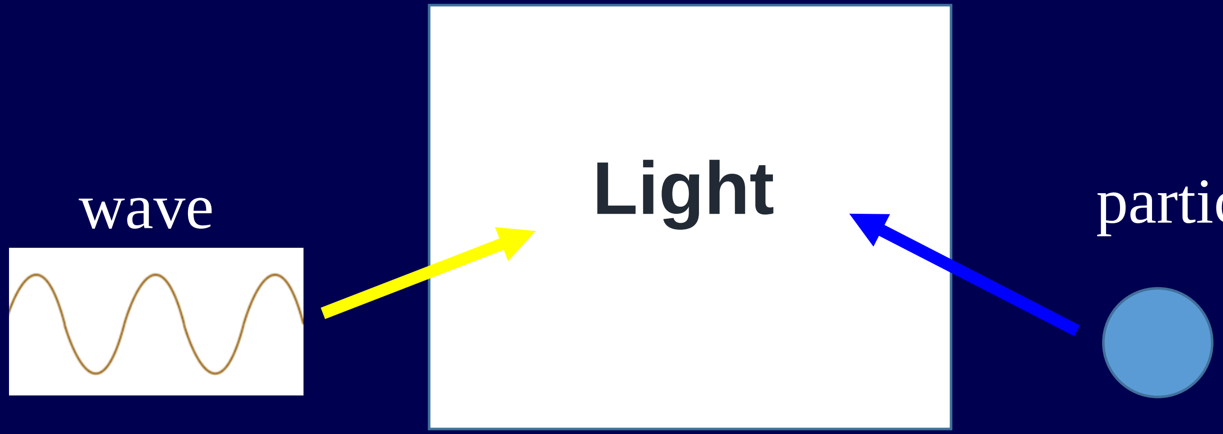


Is object “A” circle ? or rectangular?

→It depends on our observational way.
It sometimes shows us a circle, sometimes a rectangular

First strategy:
use of simple exp. demo, analogy, simple explanation

Particle-wave duality : observation of cylinder



Is "light" particle? or wave?

→It depends on our observational way.
It sometimes shows us a particle, sometimes a wave.

First strategy:
use of simple exp. demo, analogy, simple explanation

Matter wave : inverse thinking

1905, Einstein: Light (wave) is particle

1924, de Broglie: Electron(particle) is wave

→ inverse thinking in physics is popular:

Electric motor → electric generator, Speaker → microphone,
LED→ solar battery, absorption of light → emission of light in the atom, …

Second strategy:
connect modern physics with student' life

Wave-particle duality : character of person

→'Smith' is a good friend to me,
but I heard that he is a ugly man to 'Johnson'.

→If the twins have different environment,
when one becomes a physicist in a good environment,
another can become a thief in a bad environment.

Second strategy: connect modern physics with student' life

Uncertainty principle: difficulty in satisfying both

→ Mother who have two sons : umbrella seller and salt seller

→ Family and work : a workaholic is difficult to satisfy his family

Second strategy:
connect modern physics with student' life

Time dilation : feeling of time velocity in different situations

→Time goes slowly when it's hard, but time goes fast when it's fun.

: Objective time ←→Subjective time

: there is no absolute time

Second strategy:
connect modern physics with student' life

Superposition of quantum states : mixed state before decision making

Collapse of quantum state by observation : decision to one of several options

→ Before vacation: "Shall we go to the mountains on this vacation?
or shall we go to the sea?"

→ Tom ask, "Where are you going on this vacation? Make up your mind. Now!"

→ "Okay! I will go to the mountains."

This is not to go to the mountain because it is supposed to go to the mountain.
This decision is a result of collapse from two mixed options.

Third strategy:

change fundamental metaphysical belief and assumption

Causal determinism : Probability

→ Causal determinism: Today I'm giving a presentation here
because of some kind of behavior such as making something
when I was 7 years old.

→ Probability: Some kind of behavior such as making something
when he was 7 years old
makes him probable to become a scientist in the future.

→ Probability interpretation in quantum mechanics is more plausible.

Third strategy:

change fundamental metaphysical belief and assumption

Realism : result of interaction between the reality and observer

→ Temperature of water is 60˚C
: This is not the real/original temperature of water
but the result of interaction between water and thermometer

→ Uncertainty principle is so natural, it is not a strange thing.

Basic purpose of the 2nd and 3rd strategies is to indicate that modern physics is not strange/counter-intuitive story, but plausible/natural story

Conclusion

3 Reasons for teaching modern physics to MHSS

→ modern physics is about 100 years old,

→ modern society is applied with modern physics

→ students want to learn modern physics

Basic difficulty in teaching modern physics to MHSS

→ strict coherency and hierarchy of concepts

Suggestion of assumption to teach modern physics to MHSS

→ familiarity assumption

Conclusion

3 strategies for increasing familiarity with modern physics

→ use of simple demo/exp./explanation, analogy, simulation, ..

→ connection of modern physics with students' everyday life

→ change of basic metaphysical belief such as realism, causal determinism, …

Becoming familiar with modern physics

does not mean accurate understanding of modern physics.

but give a starting point and base for more deep understanding of it.

Need to study a link between familiarity and conceptual understanding.