

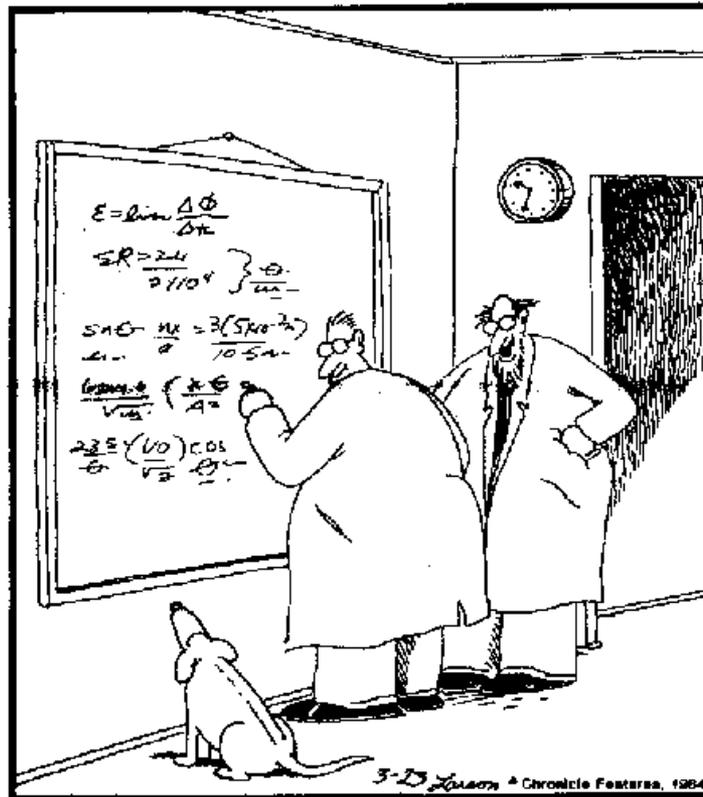
This is pages 2 - 3. It is the LAST chapter! Wohoo! It is mostly Regents level material with some Honors/SAT II things tossed in.

We're cramming the last one hundred years of physics into two weeks. We'll jump around from topic to topic. Ask for help as we go.

Modern Physics

THE FAR SIDE

By GARY LARSON



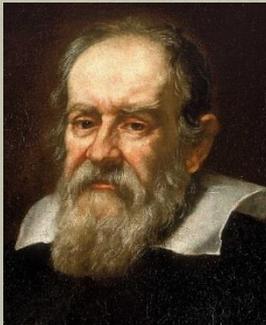
"Ohhhhhhh . . . Look at that, Schuster . . .
Dogs are so cute when they try to comprehend
quantum mechanics."

Classical Physics

(pre 1900's):

- Newtonian mechanics
 - ◆ Deterministic
 - ◆ small velocities
large distances

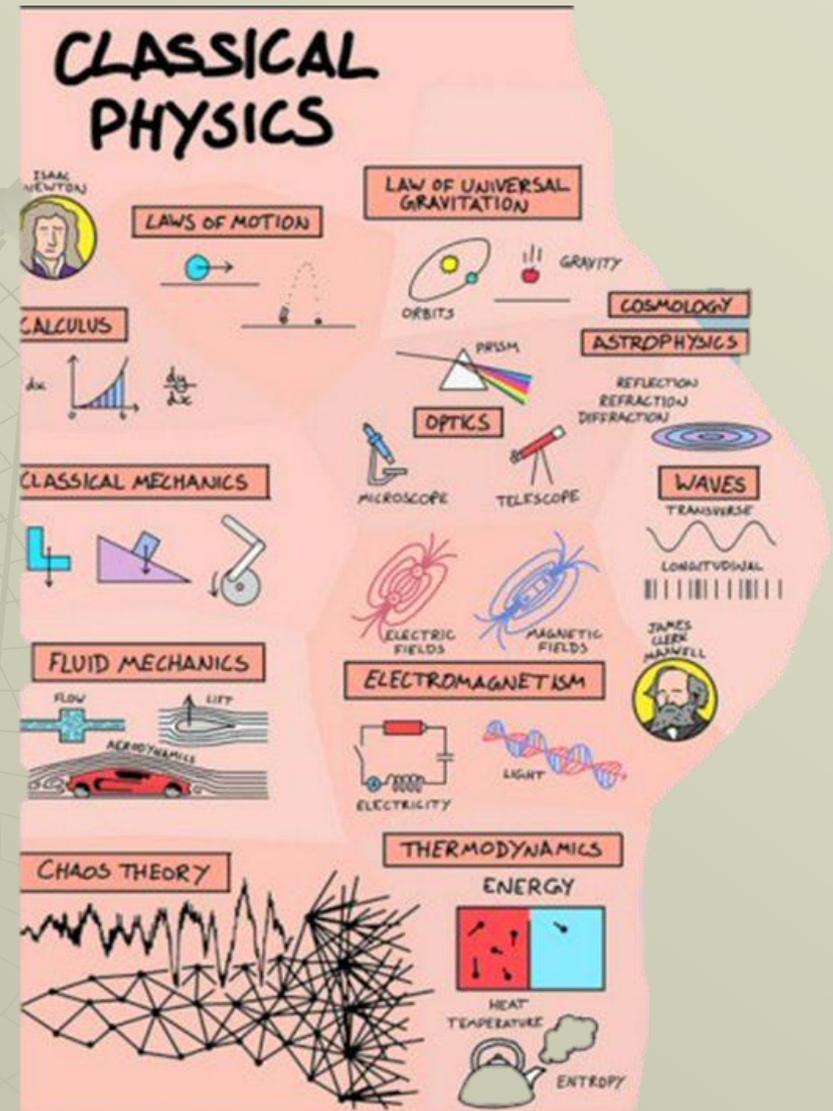
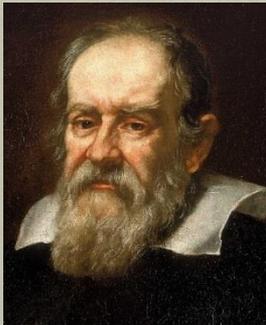
Classical physics is everything we've studied so far. You always get the same results, nothing is random



Classical Physics

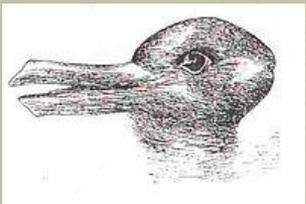
(pre 1900's):

- Newtonian mechanics
 - ◆ Deterministic
 - ◆ small velocities
large distances



Paradigm Shift

A paradigm shift is a dramatic change in methodology or practice.



Do you see a duck, a rabbit, or can you see both?

CLASSICAL PHYSICS



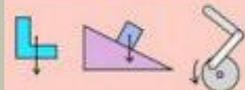
ISAAC NEWTON
LAWS OF MOTION



CALCULUS



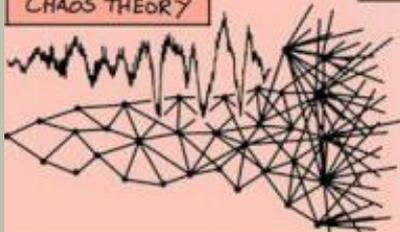
CLASSICAL MECHANICS



FLUID MECHANICS



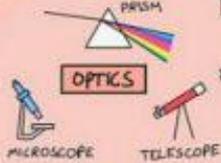
CHAOS THEORY



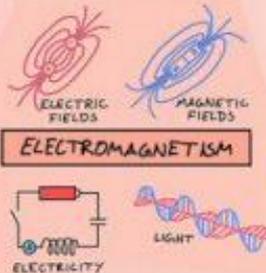
LAW OF UNIVERSAL GRAVITATION



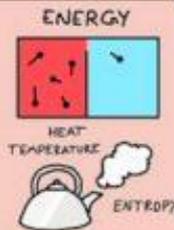
OPTICS



ELECTROMAGNETISM



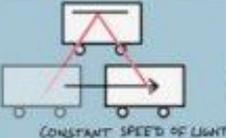
THERMODYNAMICS



RELATIVITY

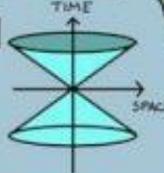


ALBERT EINSTEIN
GENERAL THEORY OF RELATIVITY

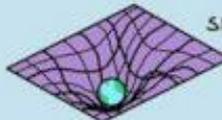


CONSTANT SPEED OF LIGHT
SPECIAL THEORY OF RELATIVITY

$E=mc^2$



SPACETIME



ASTROPHYSICS

REFLECTION REFRACTION DIFFRACTION

WAVES



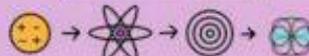
JAMES CLERK MAXWELL

QUANTUM FIELD THEORY

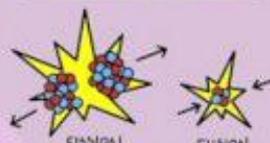


THE STANDARD MODEL

ATOMIC THEORY



NUCLEAR PHYSICS



CONDENSED MATTER PHYSICS



QUANTUM PHYSICS

YOUTUBE.COM/USER/DOMINICWALLIMAN @DOMINICWALLIMAN

PHILOSOPHY

PHILOSOPHY OF SCIENCE

FREE WILL

HOW COME?

NATURE OF REALITY

JUST...WHY?

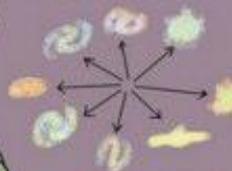
THE CHASM OF IGNORANCE

THE FUTURE

QUANTUM GRAVITY



DARK ENERGY



DARK MATTER



AND MANY MORE

PARTICLE PHYSICS

Modern Physics

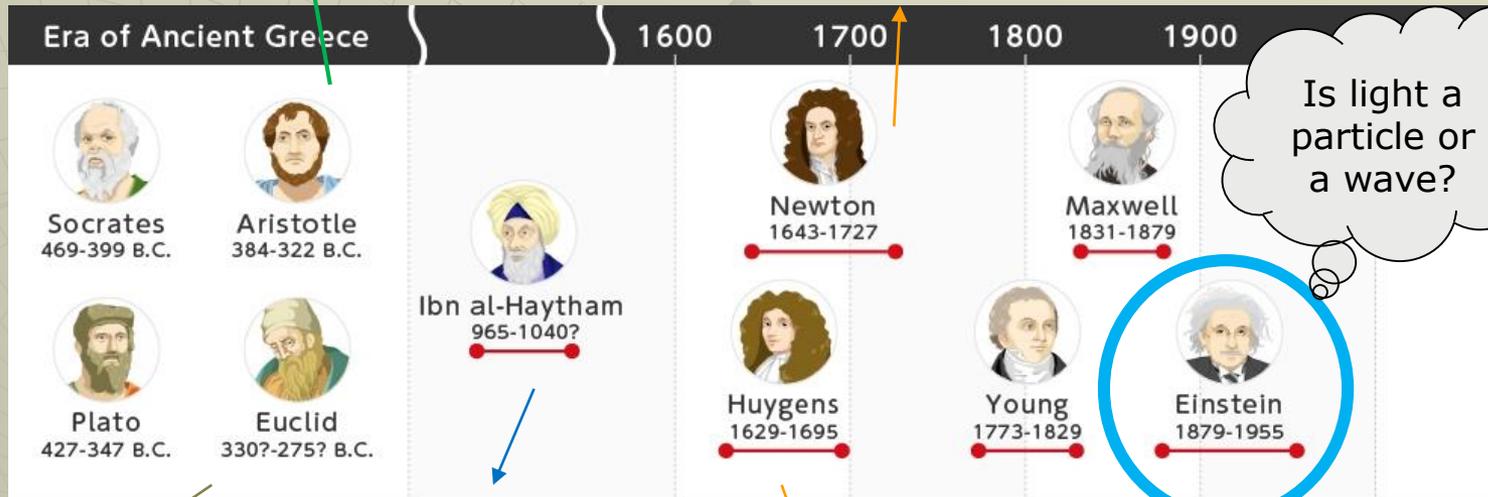
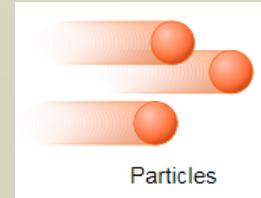


(1900's – Present):

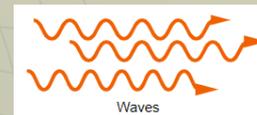
- Special Relativity:
very fast
- General Relativity:
very large
(massive) – gravity
- Quantum Mechanics:
very small

This is what we're going to be covering now – the new stuff

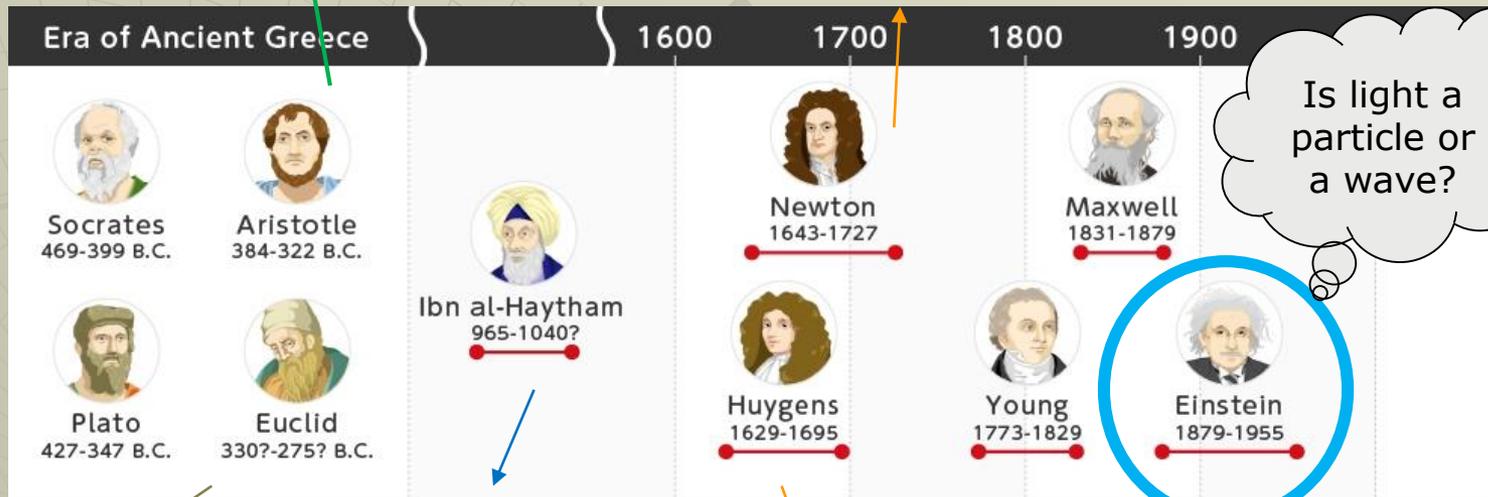
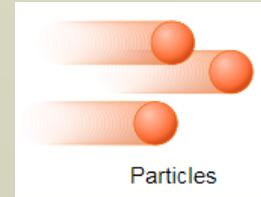
“The essence of light is white light. Colors are made up of a mixture of lightness and darkness.”



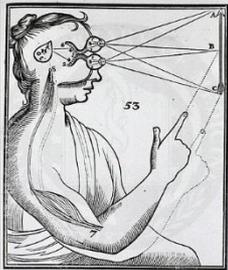
fundamental knowledge of optics, such as reflection, diffusion and vision, into a book called “Optics”.



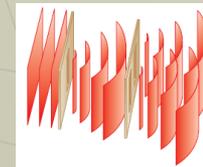
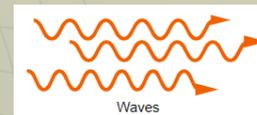
“The essence of light is white light. Colors are made up of a mixture of lightness and darkness.”



Is light a particle or a wave?



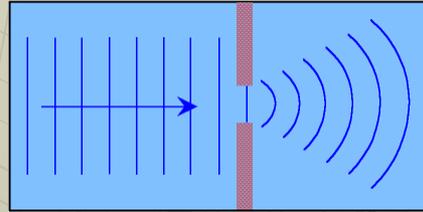
fundamental knowledge of optics, such as reflection, diffusion and vision, into a book called “Optics”.



It all starts with light – is it a wave or a particle?

What proof exists that light is a wave?

◆ Diffraction



◆ Interference

INTERFERENCE

Destructive



+



=



Constructive



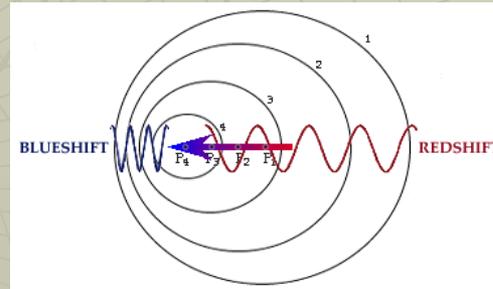
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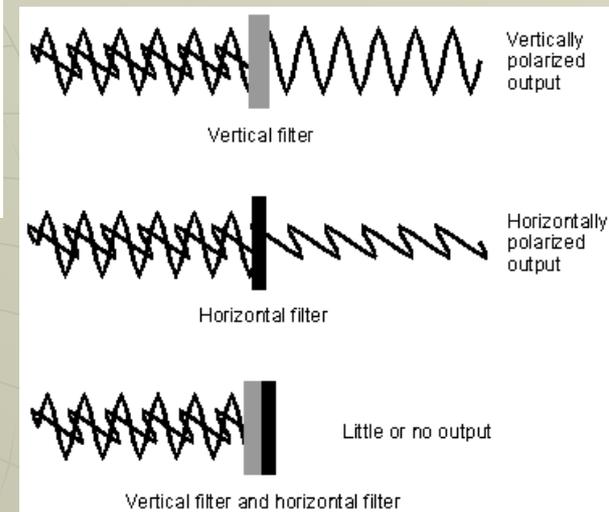
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◆ Doppler Effect

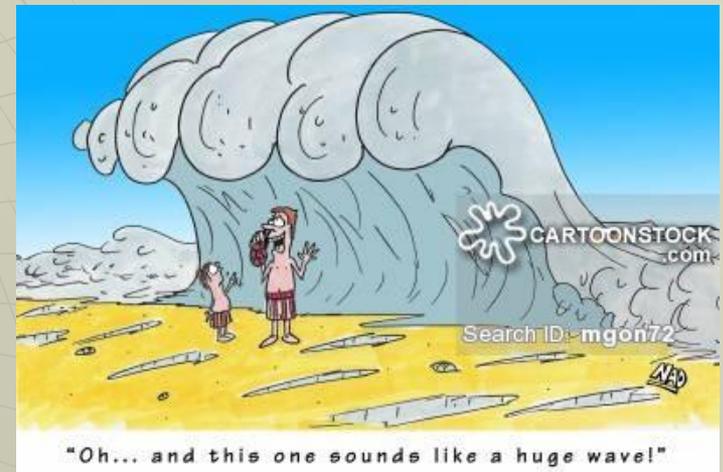
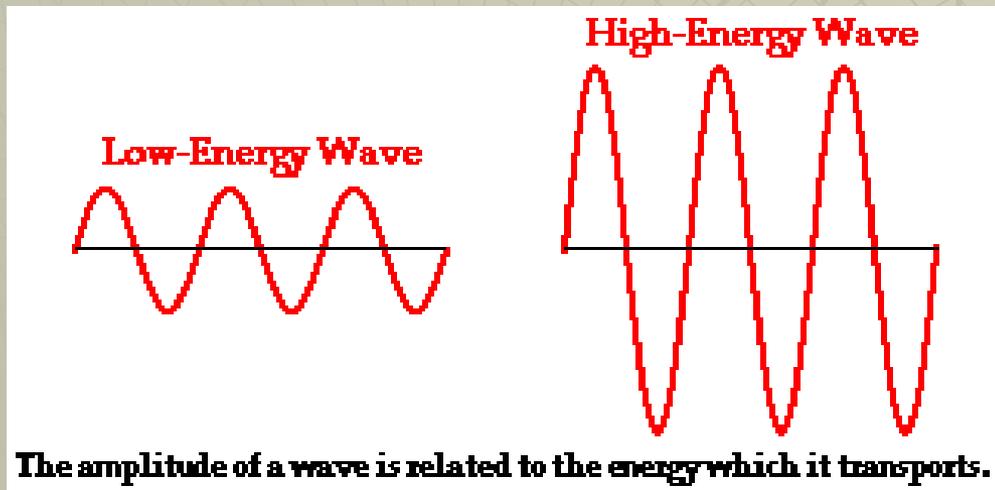


◆ Polarization

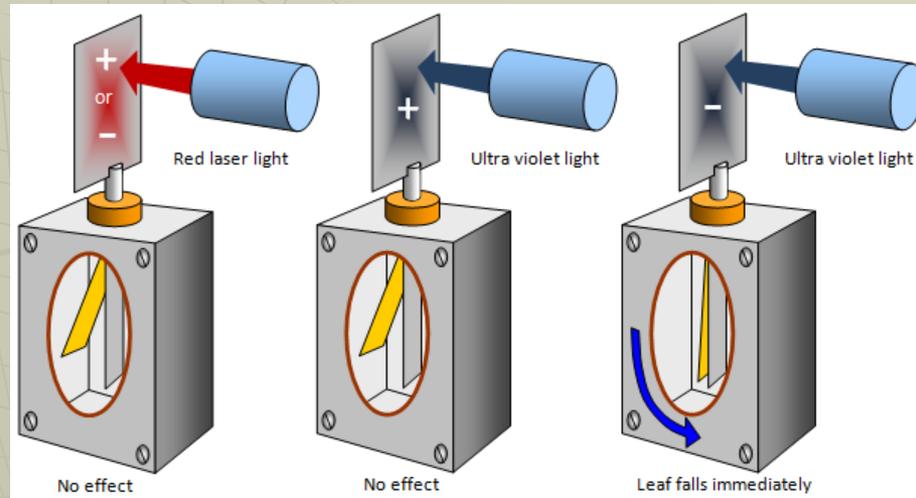


Classical Theory says . . .

- ◆ light acts as a wave and the energy of a wave depends on its amplitude (intensity) not its frequency.



The Photoelectric Effect



When light falls on a metal surface, it emits electrons. But only if the light has a high enough energy

The Photoelectric Effect

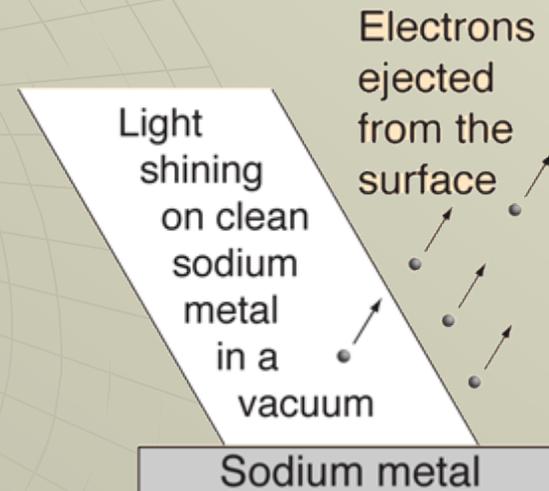
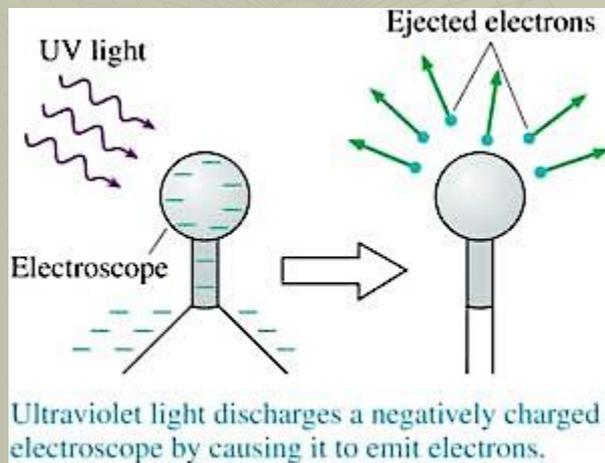


<https://www.youtube.com/watch?v=z-3XaXCvjZw>

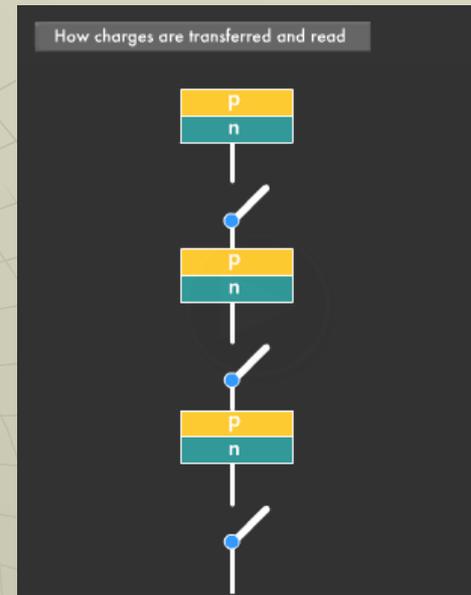
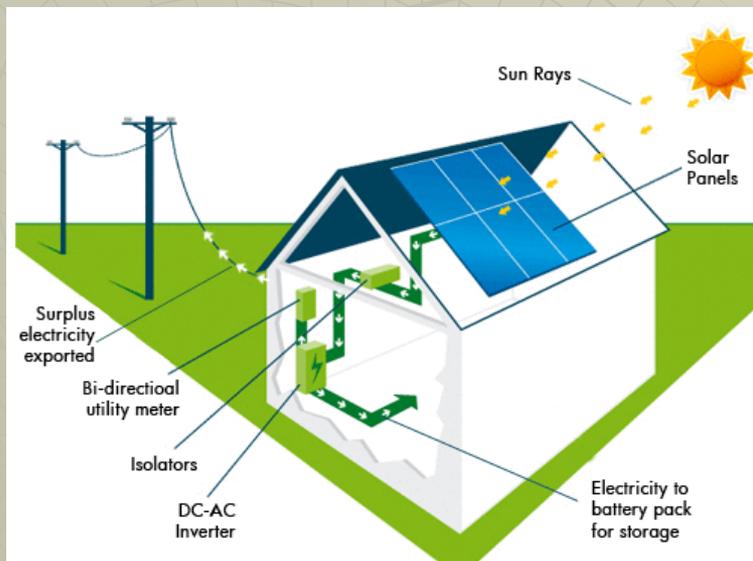
Watch the video. Normally I would do this demo for you.

What proof exists that light is a particle?

- ◆ The Photoelectric Effect – the emission of electrons from a metal when electromagnetic radiation of high enough frequency (or low enough wavelength) falls on the surface.



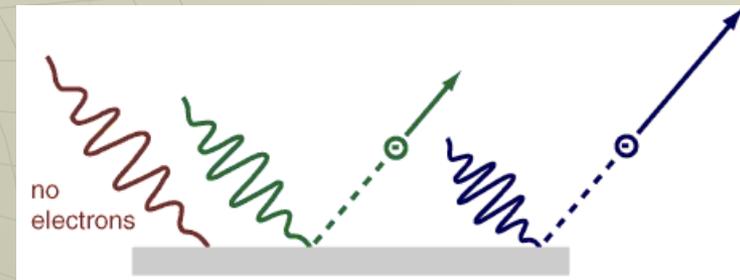
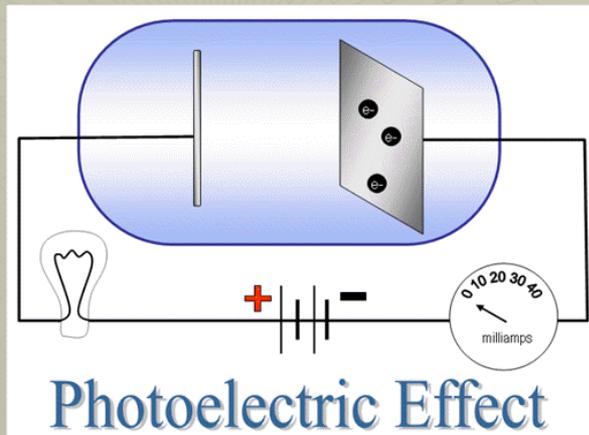
◆ Practical application: solar cells, CCD cameras



The Experiment

- ◆ 1. Light of varying frequencies and intensities are shone on a metal surface (photoemissive surface).

Photoemissive = ability to give off electrons due to photoelectric effect



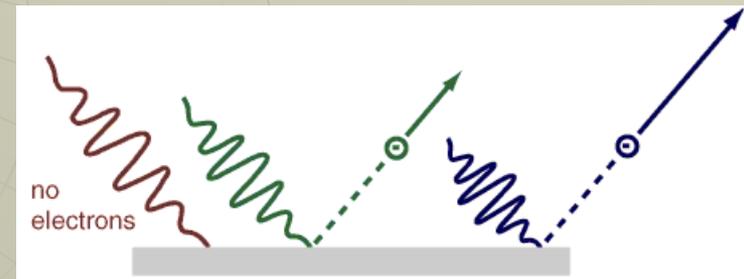
The Experiment

- ◆ 2. Light below a certain frequency will not emit electrons (photo-electrons) no matter how intense it is or how long it shines on the surface. Light at or above a certain frequency will immediately emit electrons no matter how intense it is.

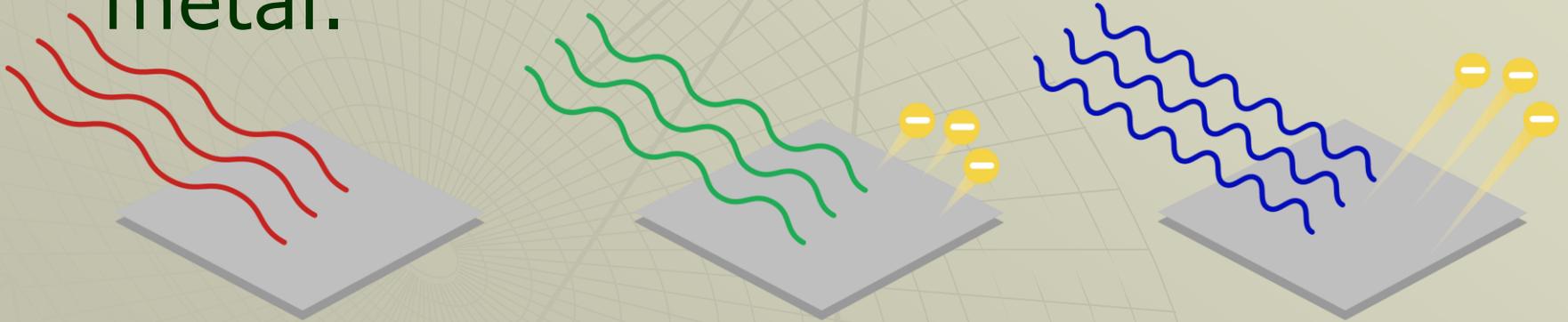
Below a certain frequency = never works, no matter how bright the light is

Above a certain frequency = always gives off electrons

Photo-electrons = electrons given off during photoelectric effect



- ◆ Threshold frequency (f_0) – minimum frequency of light needed to eject electrons from the surface of the metal.



Below a certain frequency = never works, no matter how bright the light is

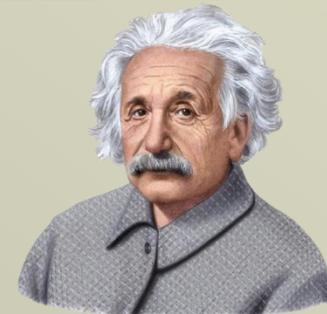
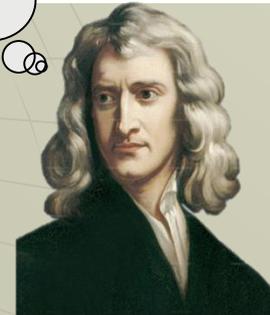
Above a certain frequency = always gives off electrons

Einstein noted that careful experiments involving the photoelectric effect could show whether light consists of particles or waves.

	Classical predictions	Experimental evidence
Whether electrons are ejected or not depends on . . .	Intensity of the light (If intense enough, electrons will be ejected no matter what the frequency)	Frequency of the light
The maximum kinetic energy of the ejected electrons depends on . . .	Intensity of the light	Frequency of the light
At low intensities, ejecting electrons . . .	Takes time	Occurs instantaneously above threshold frequency (never occurs below certain frequency)



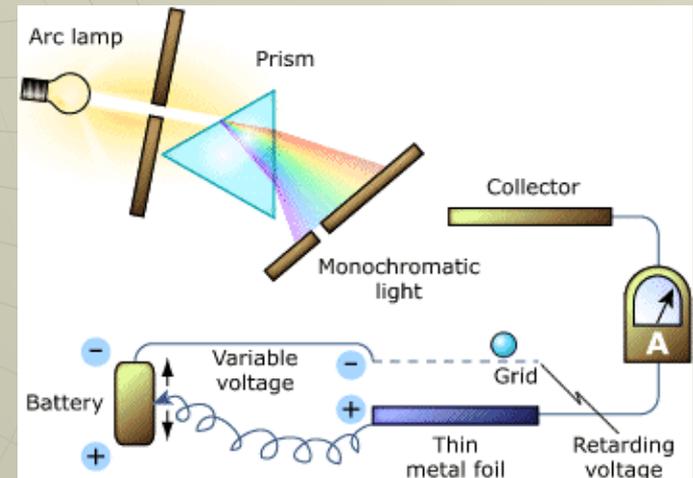
Analysis of Results: **conflicts** with the classical theory about light



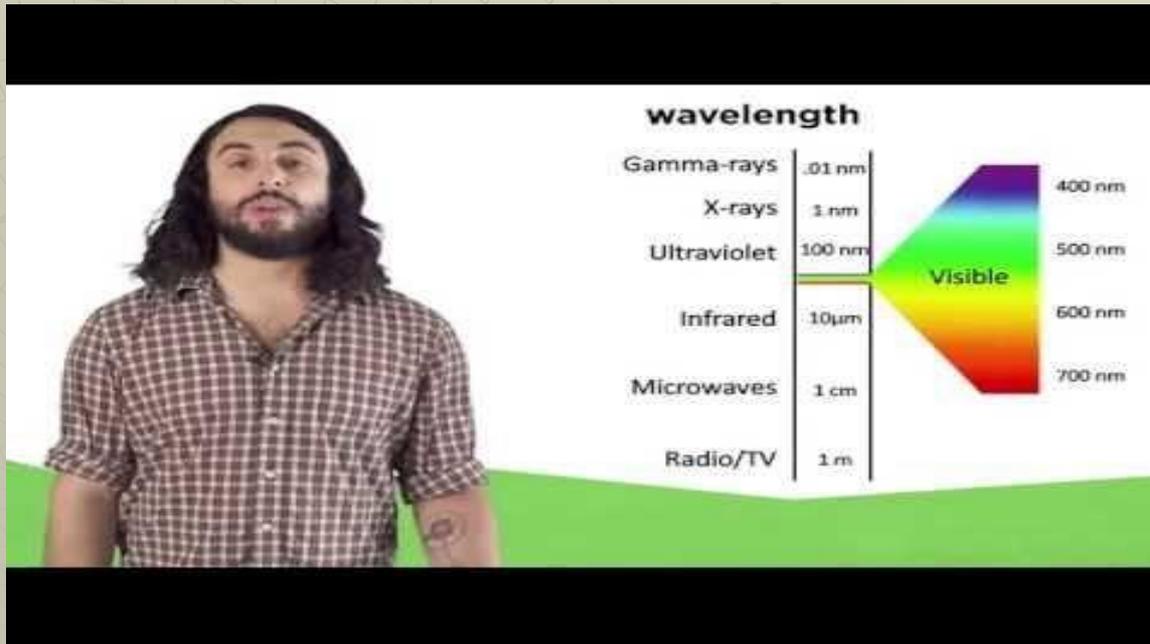
Quantum Theory says . . .

- ◆ light (and all electromagnetic radiation) sometimes acts like a particle whose energy depends on its frequency
 - light can exhibit properties of **BOTH** waves and of particles.

Vindicated!

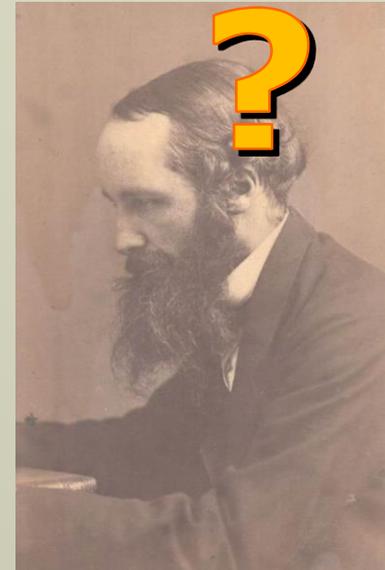
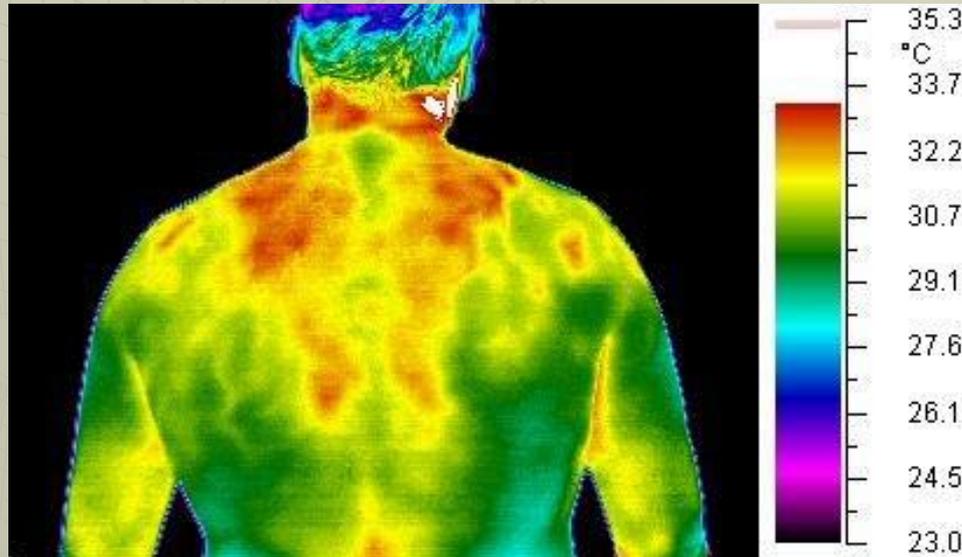
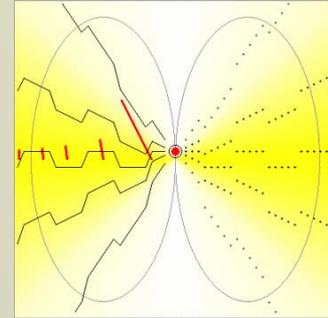
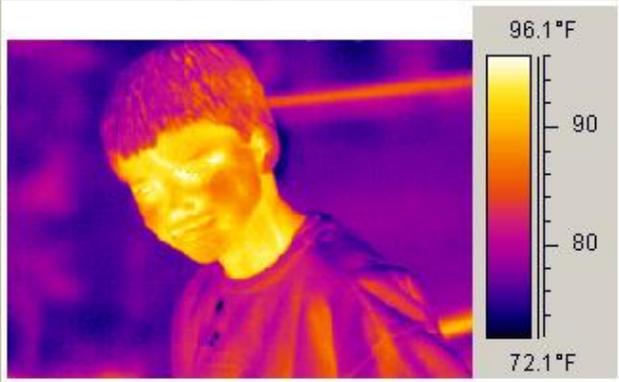


Watch the video.



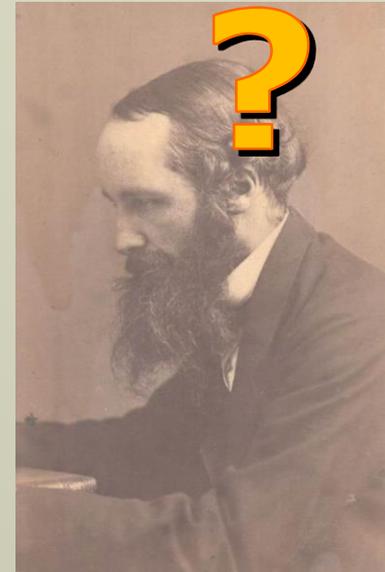
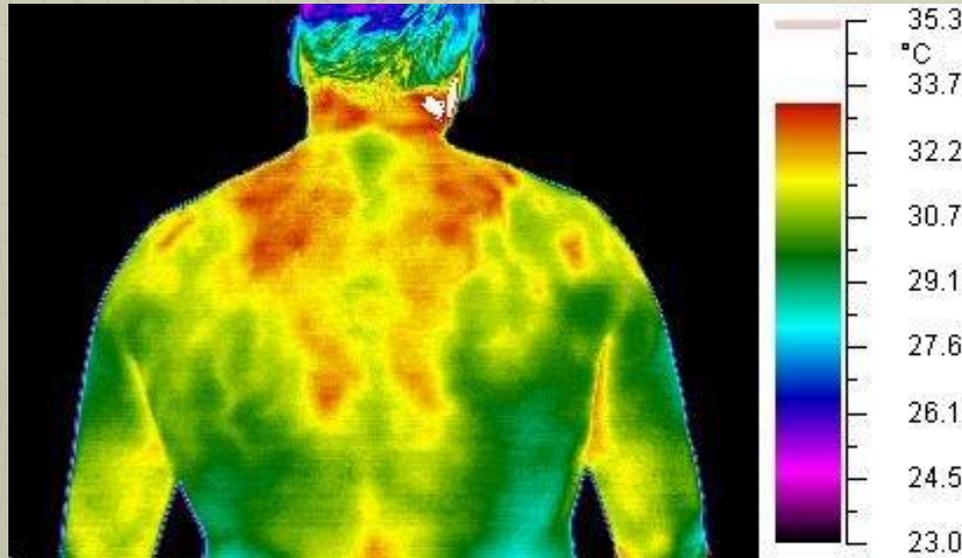
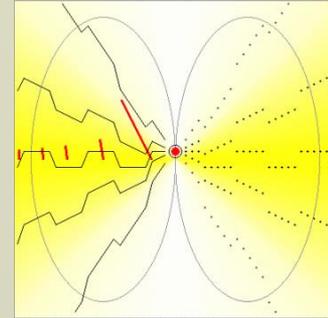
<https://www.youtube.com/watch?v=MFPKwu5vugg>

Blackbody Radiation

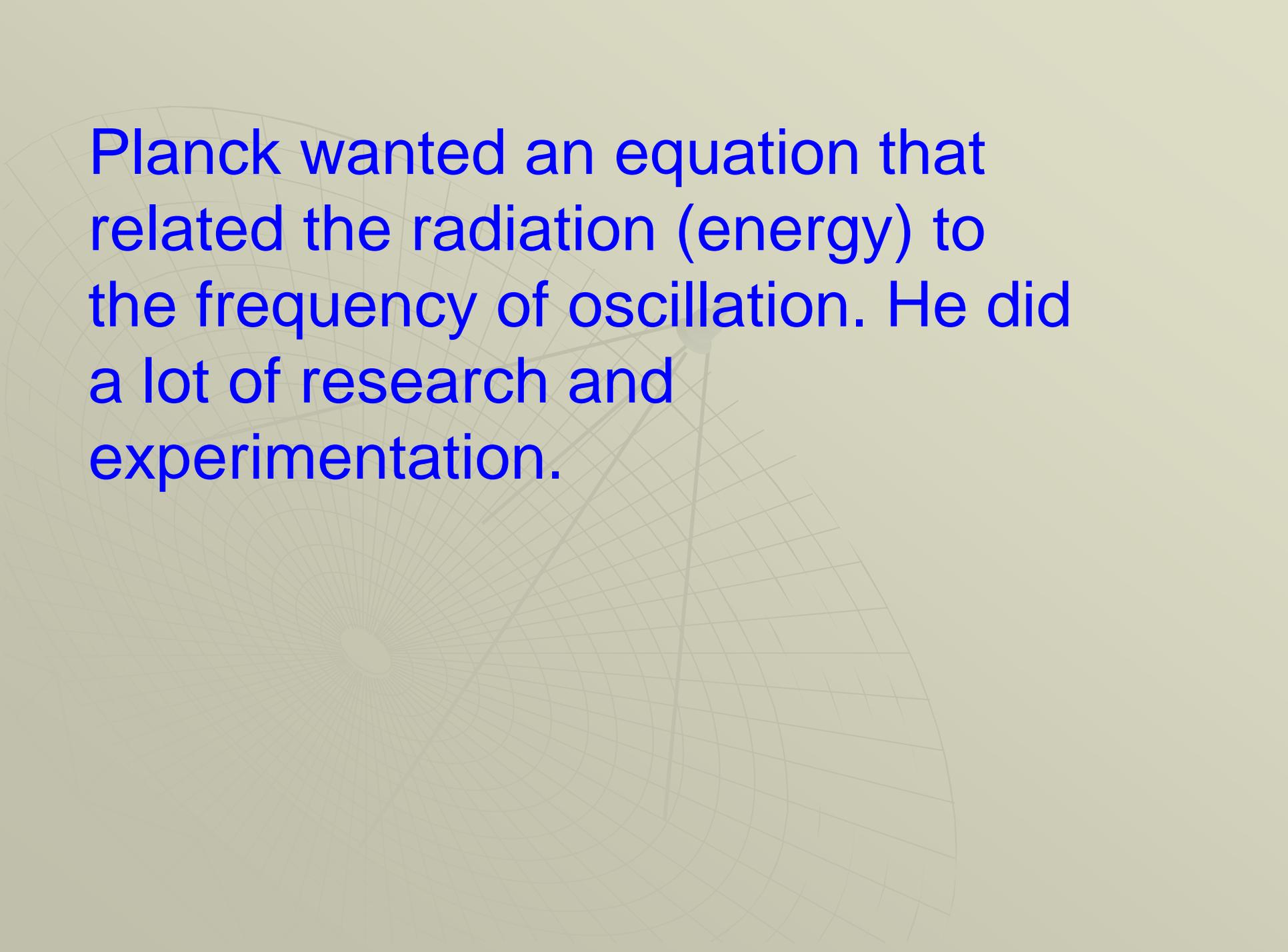


What kind of energy is heat?

Blackbody Radiation



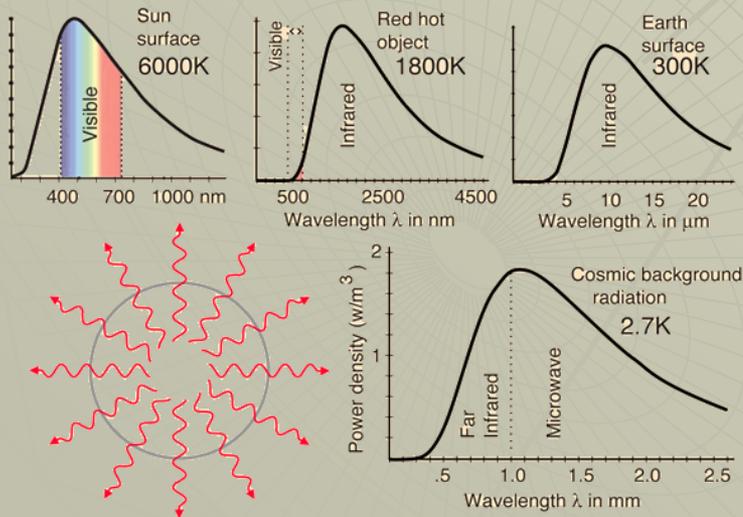
Infrared radiation for human body temperature



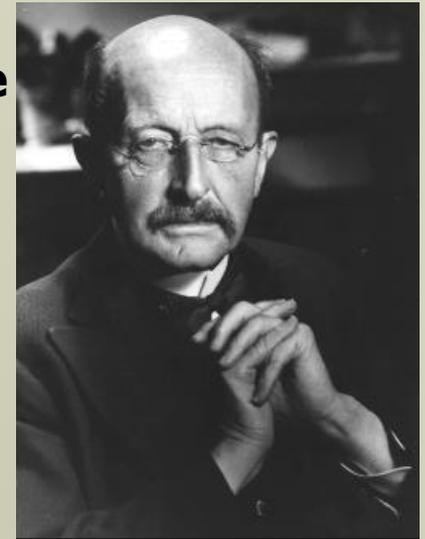
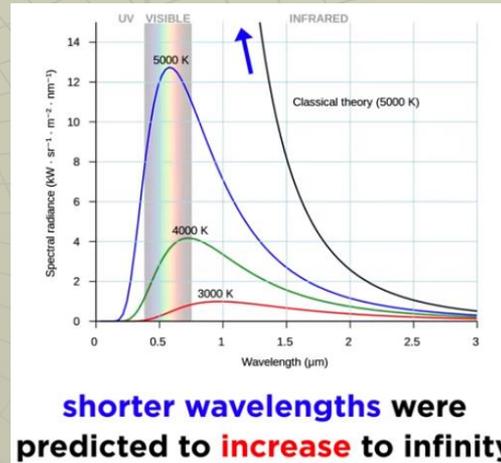
Planck wanted an equation that related the radiation (energy) to the frequency of oscillation. He did a lot of research and experimentation.

Blackbody Radiation

- ◆ In 1900, Max Planck was working on the problem of how the radiation an object emits is related to its temperature. He came up with a formula that agreed very closely with experimental data.



The UV Catastrophe



Planck's Constant



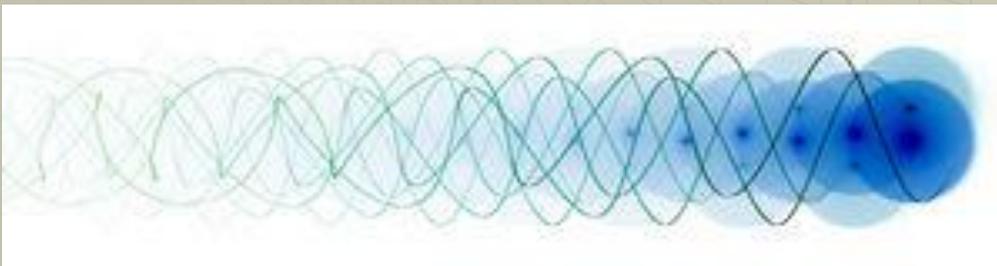
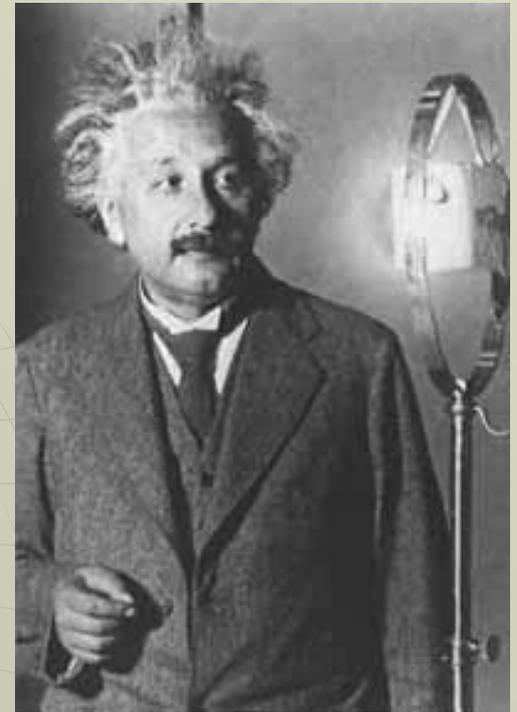
- ◆ Max Planck's formula only made sense if he assumed that the energy of a vibrating molecule was quantized - could only take on certain values

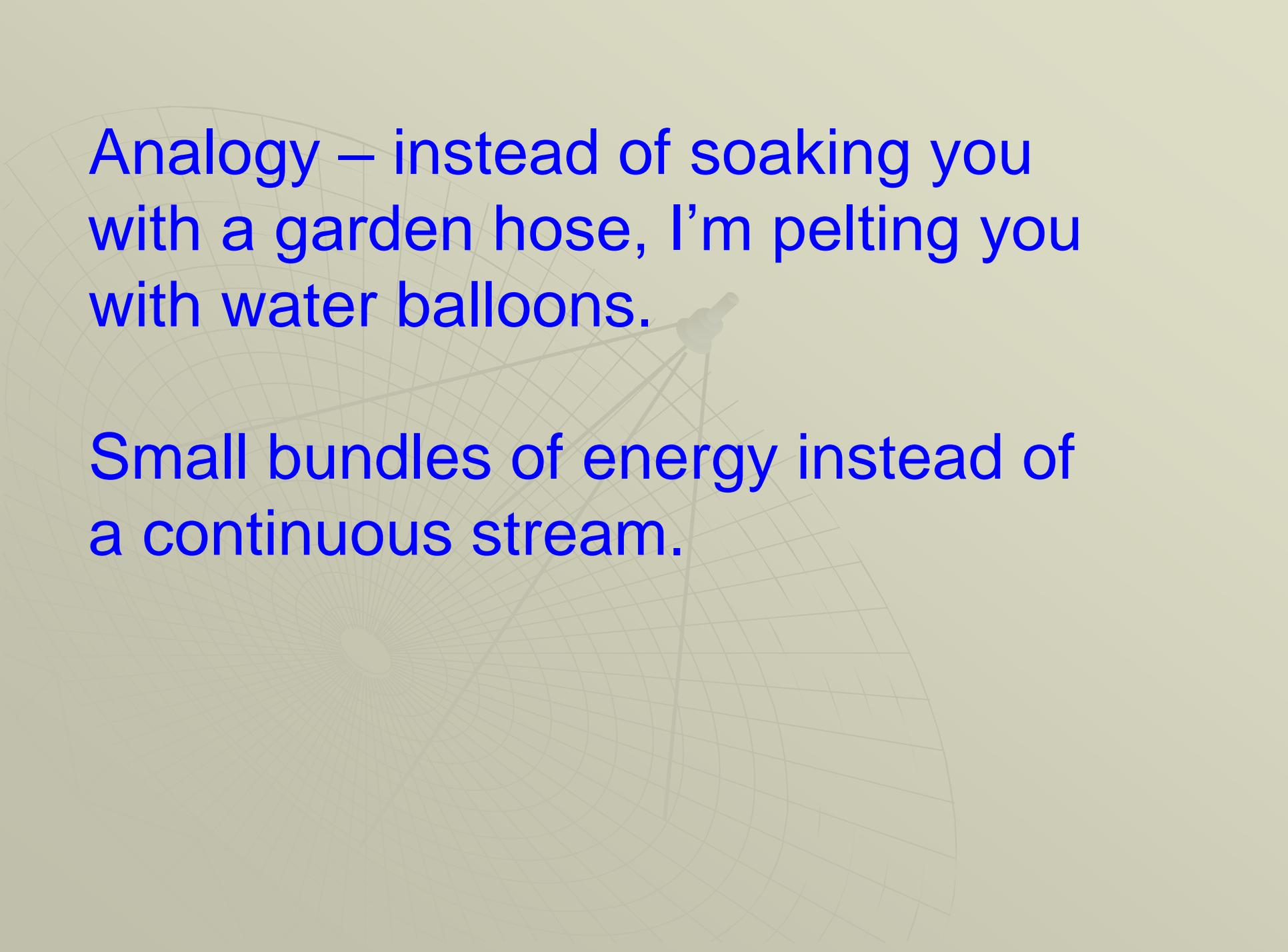
Planck didn't understand his equation – why were they grouped together? Why not a continuous spectrum? Why a weird multiplier value?

He asked for help.... from his buddy Einstein.

Planck's Constant

- ◆ Based on Planck's work, Einstein proposed that light delivers its energy in chunks, meaning light consists of little bundles, or quanta, called photons



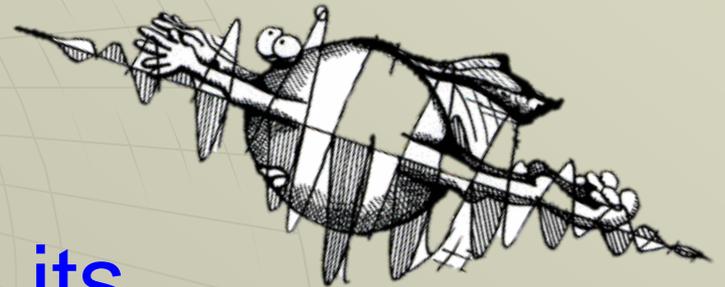


Analogy – instead of soaking you with a garden hose, I'm pelting you with water balloons.

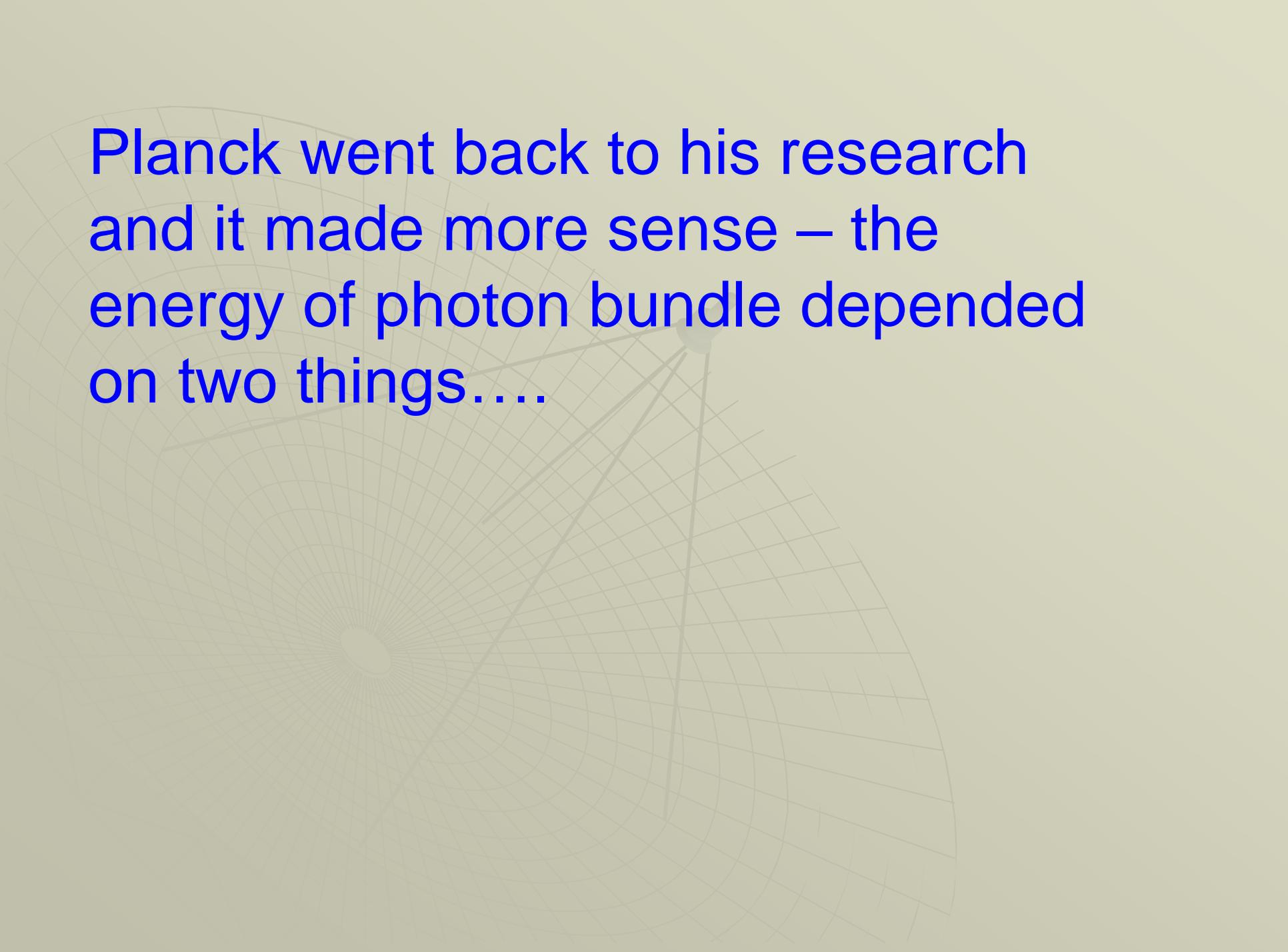
Small bundles of energy instead of a continuous stream.

Planck's Constant

- ◆ Photon (γ) – a particle of pure energy that has momentum
 - massless, and travels at the speed of light, no charge



How light delivers its energy – in a bundle



Planck went back to his research
and it made more sense – the
energy of photon bundle depended
on two things.....

Planck discovered that energy of a photon depends on

- ◆ Frequency
- ◆ Planck's constant ($h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$)

The weird multiplier was a fundamental constant, so they named it after Planck who discovered it.



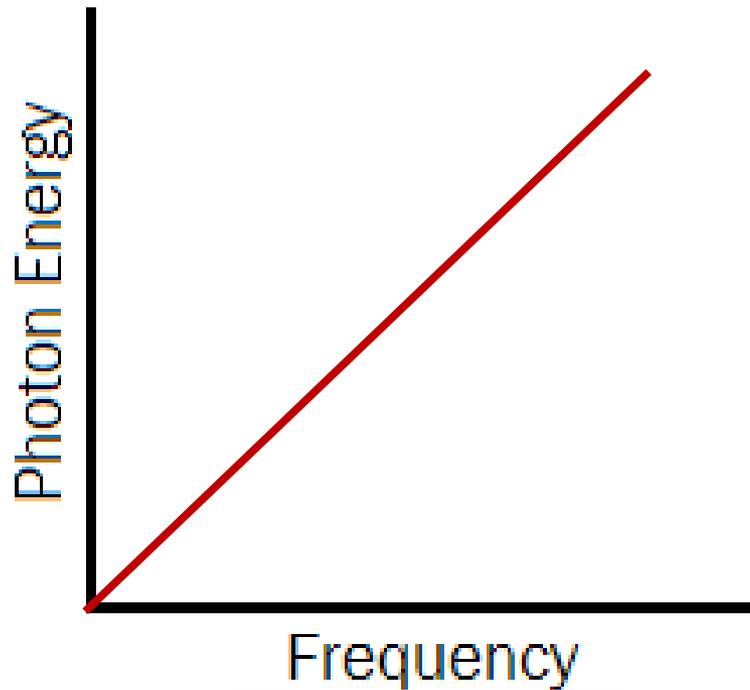
Planck discovered that energy of a photon depends on



$$E_{\text{photon}} = hf = \frac{hc}{\lambda}$$

$$h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$$

Energy of a Photon



Slope = Planck's Constant (h)

