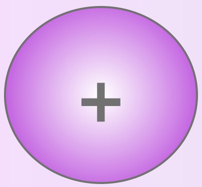
The Structure of the Atom

Review

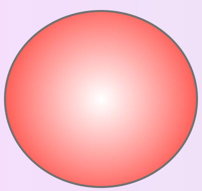
Atoms are composed of

PROTONS



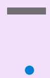
positively charged — mass = 1.6726×10^{-27} kg

NEUTRONS

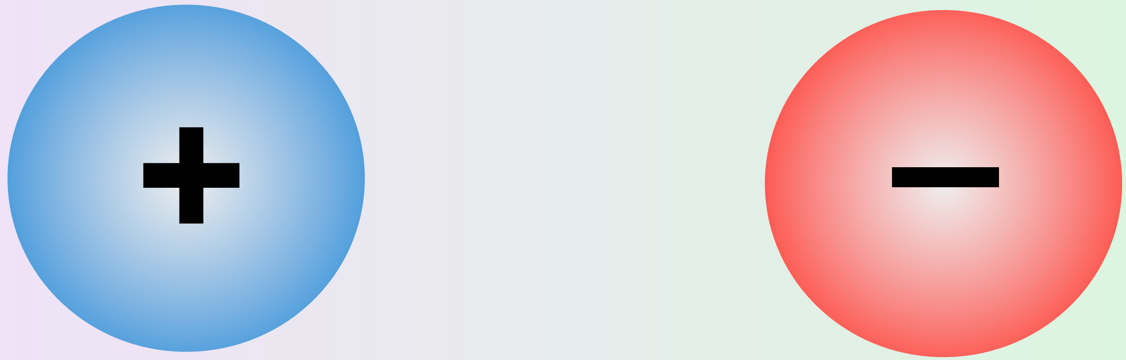


neutral — mass = 1.6750×10^{-27} kg

ELECTRONS



negatively charged — mass = 9.1096×10^{-31} kg



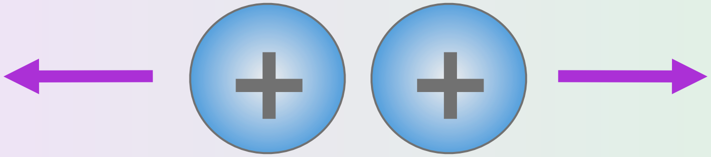
positive and negative charges

- every object normally has both kinds of charges in equal amounts
- objects with an equal amount of positive and negative charge are said to be electrically neutral

Forces between charges

Electrostatic Force

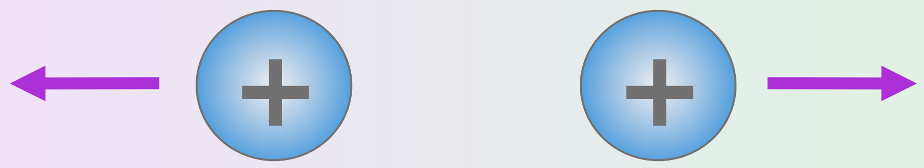
- objects with like charge repel



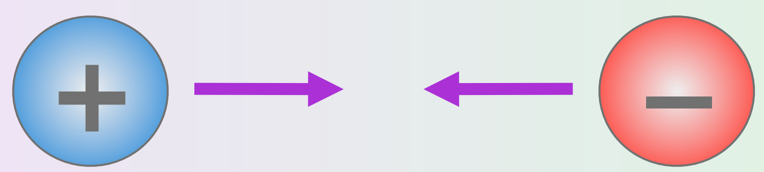
Forces between charges

Electrostatic Force

- **objects with like charge repel**



- **objects with opposite charge attract**

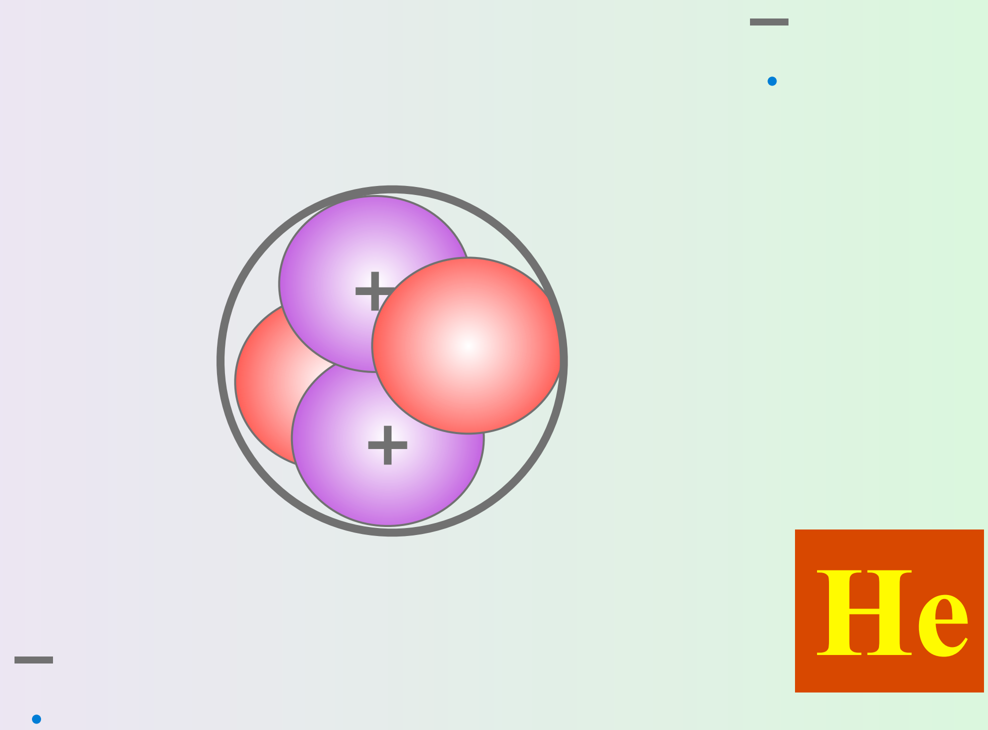


In a sense chemistry amounts to asking the following questions

What energies do individual electrons possess?

Where in an atom can electrons be found?

Our Current Model of the Atom



In a sense chemistry amounts to asking the following questions

How many electrons are present in a particular atom?

What energies do individual electrons possess?

Where in an atom can electrons be found?

From Classical Physics to Quantum Theory

The properties of atoms are not governed by the same laws of physics as larger objects

Quantum Mechanics:

the physics of the very small

To understand the electron structure of atoms, one must understand the nature of light

The Players

Erwin Schrodinger

Werner Heisenberg

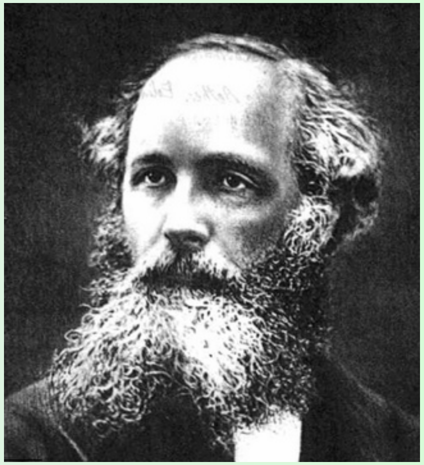
Louis Victor De Broglie

Neils Bohr

Albert Einstein

Max Planck

► James Clerk Maxwell



James Clerk Maxwell

Proposed that visible light consists of electromagnetic waves.

waves

A vibrating disturbance by which energy is transmitted.

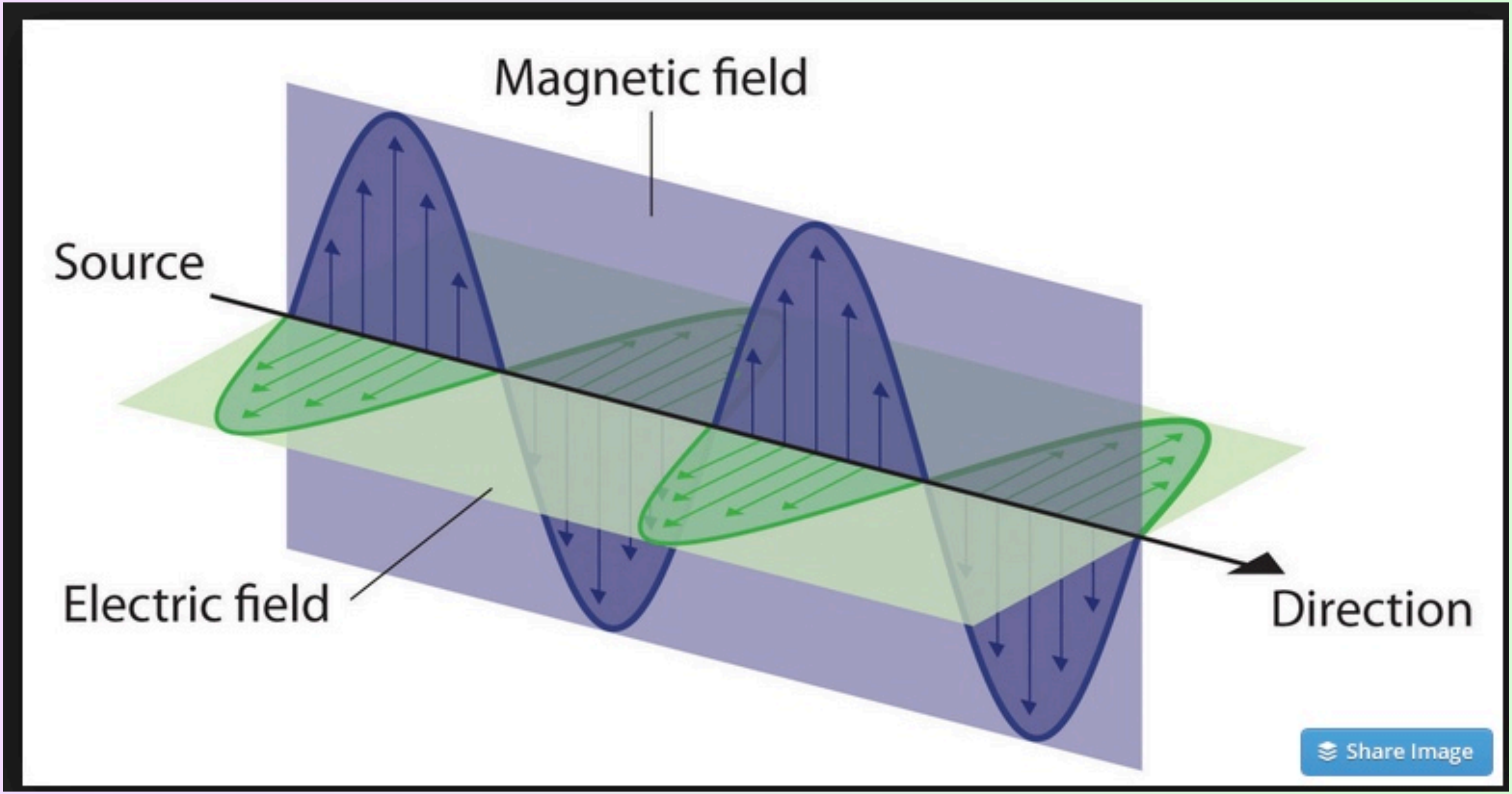
Electromagnetic radiation

is energy propagated at the speed of light

$$c = 3 \times 10^8 \text{ m/sec}$$

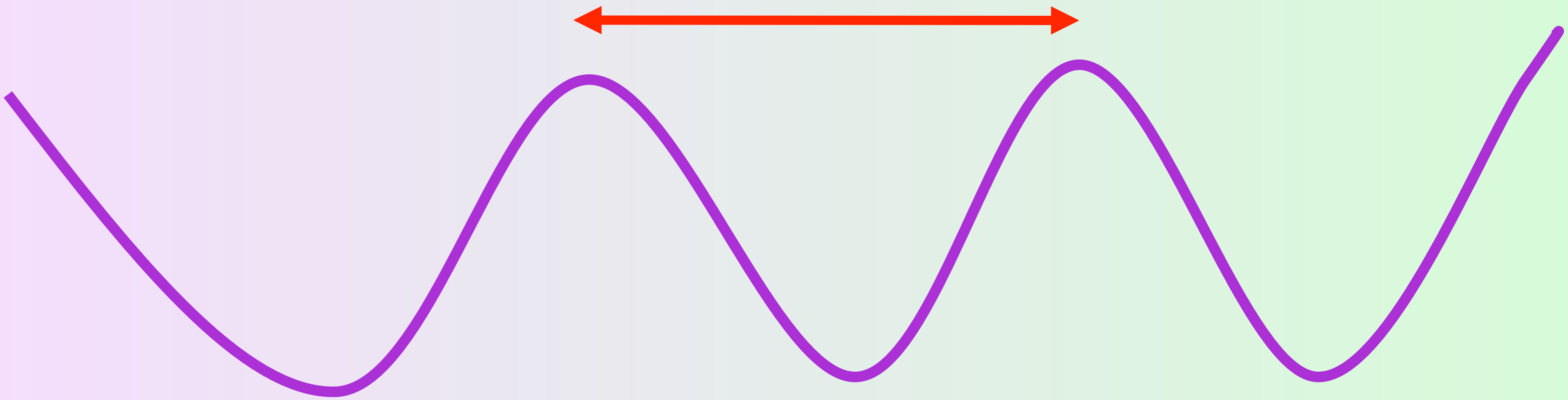
Consists of electric and magnetic fields that simultaneously oscillate in planes mutually perpendicular to each other.

Electromagnetic radiation



Properties of Waves

wavelength, λ = m

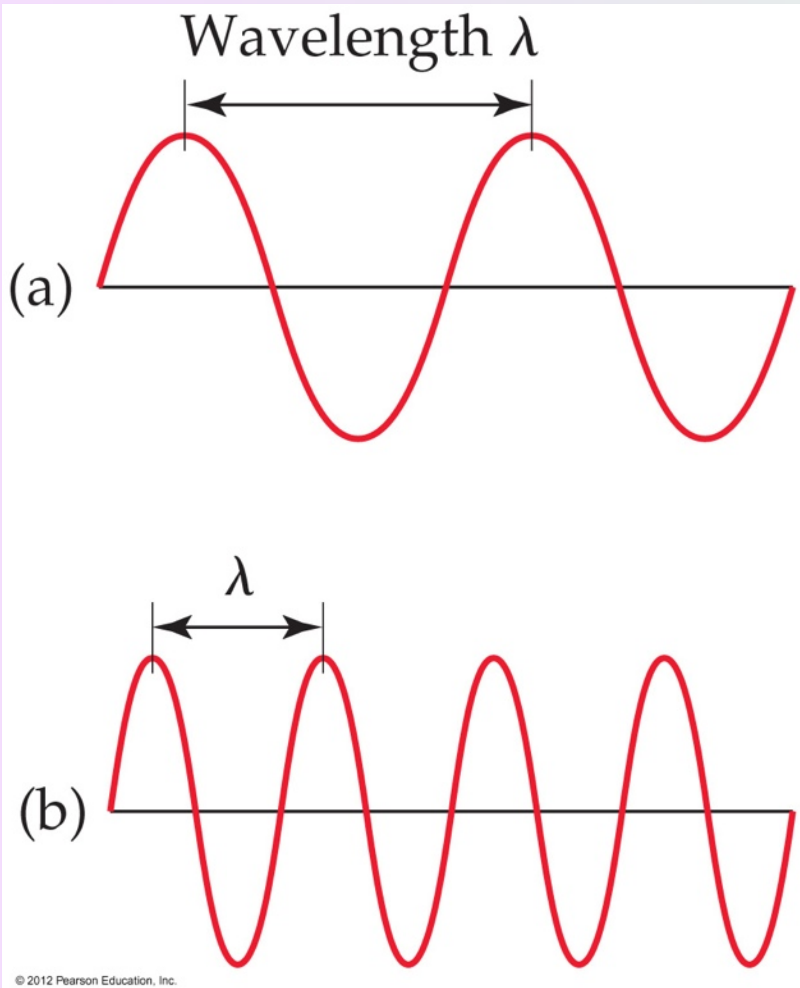


Frequency ν = 1/s = Hz (Hertz)

$$\boxed{c = \nu \lambda}$$

Frequency and wavelength are inversely proportional

$$c = \nu \lambda$$



low frequency-long wavelength

high frequency-short wavelength

Types of electromagnetic radiation

high frequency

short wavelength

gamma rays

X-rays

ultraviolet light

visible light

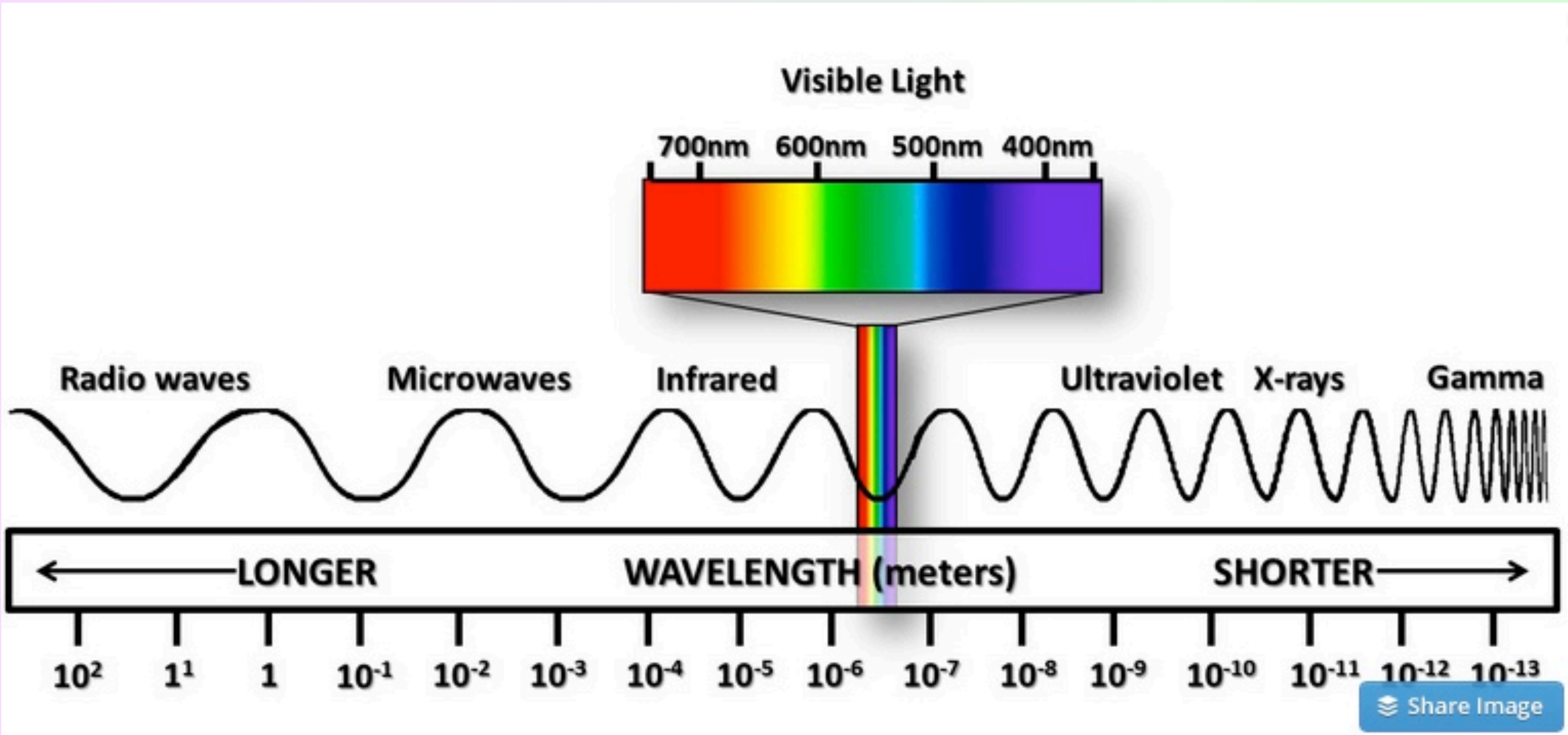
infrared radiation

microwaves

radio waves

low frequency

long wavelength



Visible Light
700nm 600nm 500nm 400nm
Radio waves
Microwaves
Infrared
Ultraviolet
X-rays
Gamma
LONGER
WAVELENGTH (meters)
SHORTER
10^2 1^1 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12} 10^{-13}
Share Image

The Nature of Energy

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The wave nature of light does not explain how an object can glow when its temperature increases.

The Players

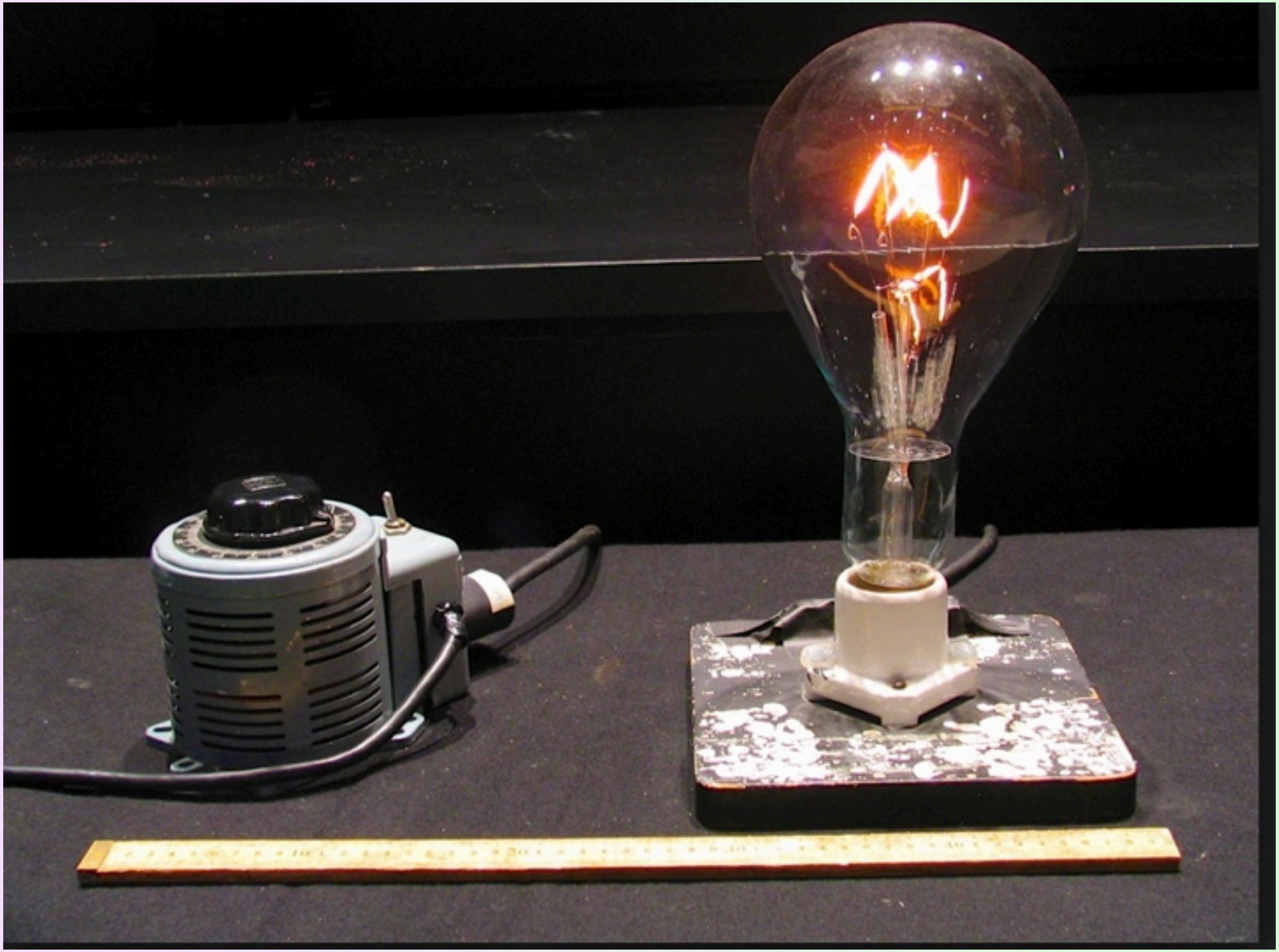
- Erwin Schrodinger
- Werner Heisenberg
- Louis Victor De Broglie
- Neils Bohr
- Albert Einstein
- Max Planck
- James Clerk Maxwell

An Observable Fact

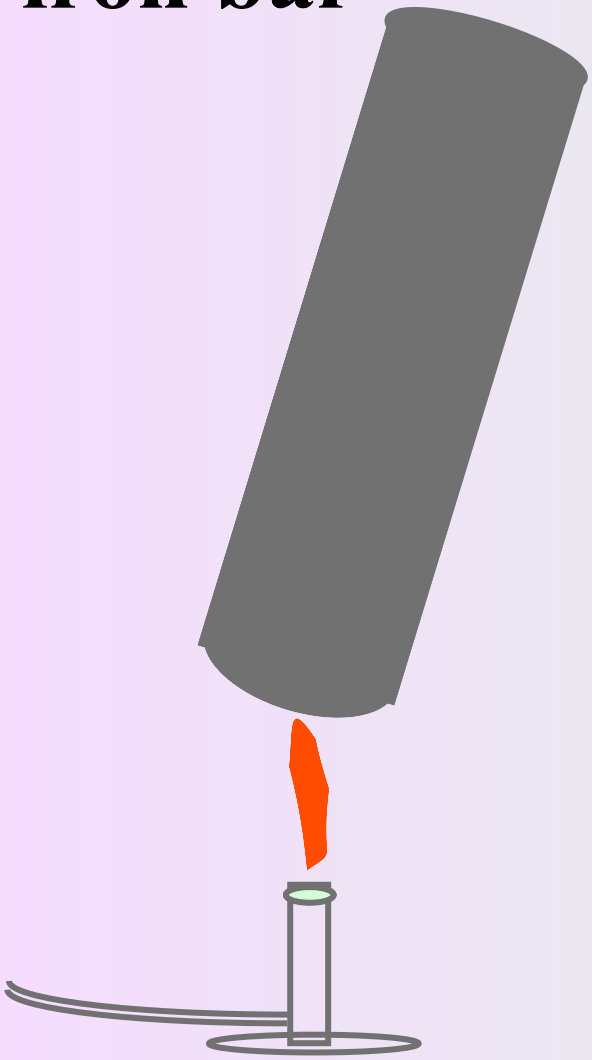
hot bodies radiate electromagnetic energy

classical physics assumed that radiating energy was continuous, due to its wavelike nature .

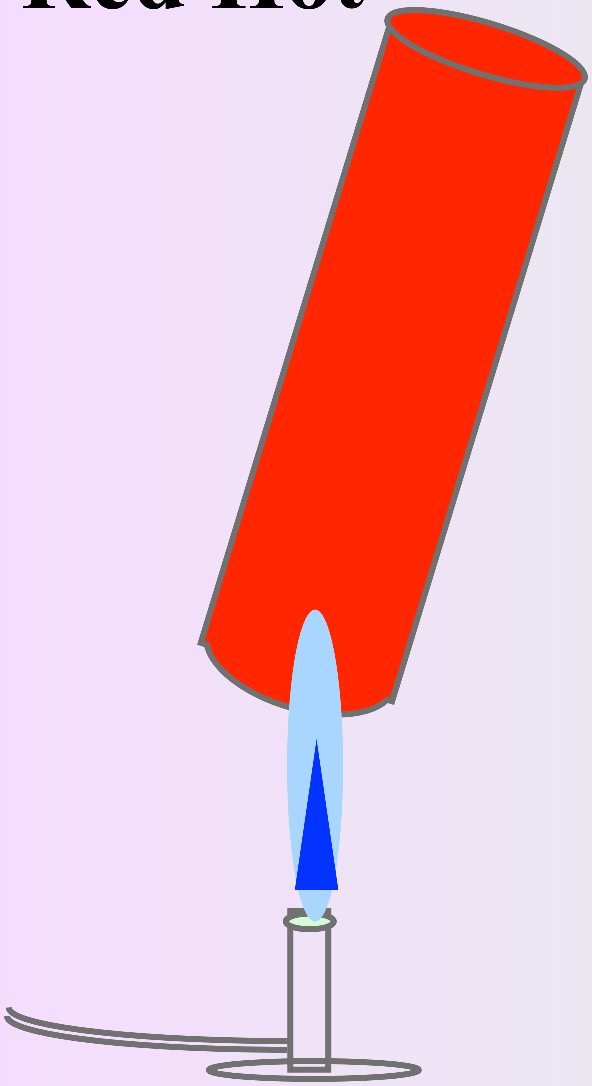

CAVALRY
Mira
Share Image



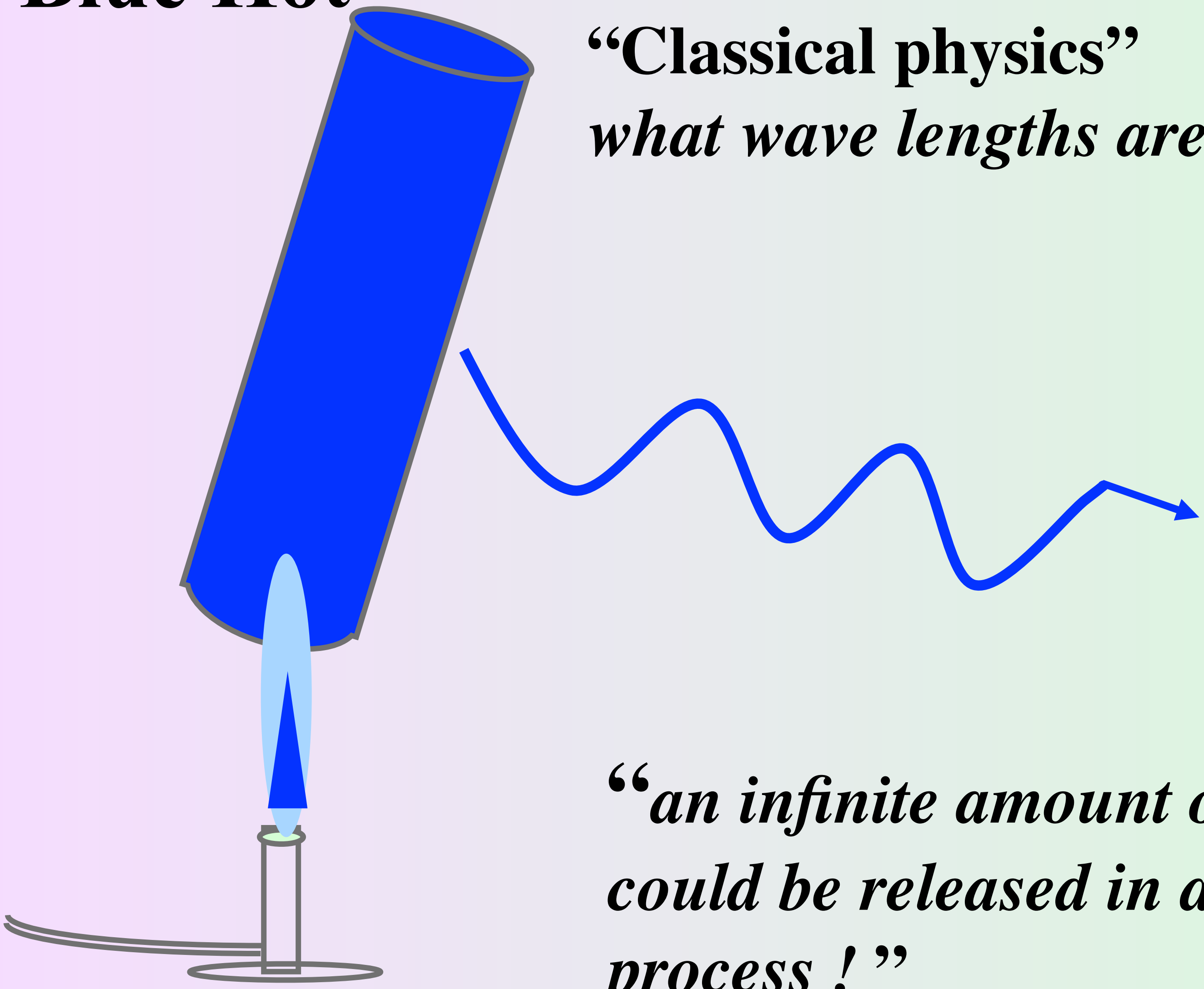
iron bar



Red Hot



Blue Hot



"Classical physics"

what wave lengths are allowed ?

"an infinite amount of energy could be released in a radiation process ! "

Max Planck

the energy of the emitted electromagnetic radiation is proportional to frequency

$$\Delta E = h\nu$$

where h = 6.626 x 10^{-34} J s

h is called Planck's constant

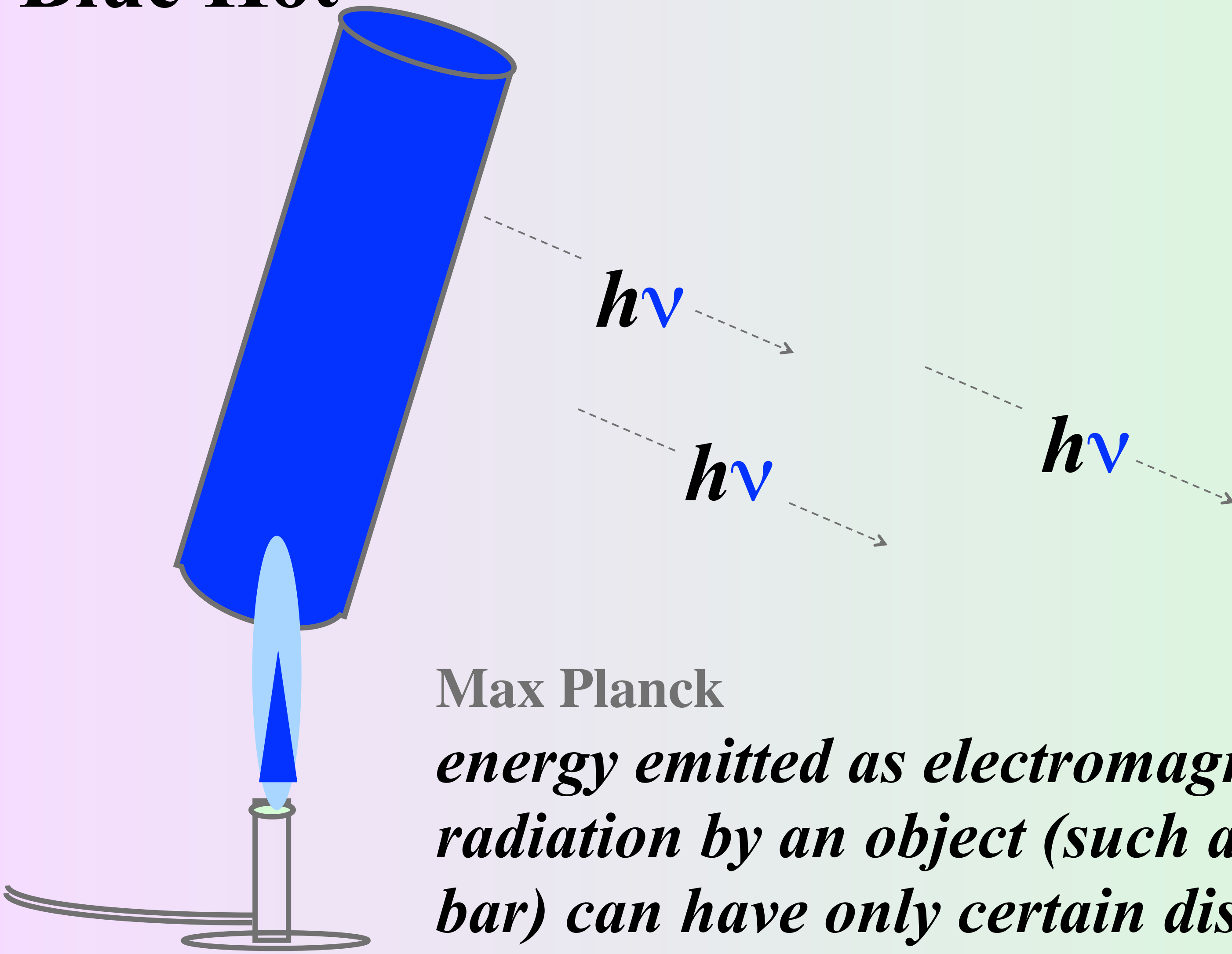
Max Planck

$\Delta E = n h\nu$

Energy is always emitted in multiples of $h\nu$.

n is a whole number (integer)

Blue Hot



Max Planck

energy emitted as electromagnetic radiation by an object (such as a hot iron bar) can have only certain discrete values,

Energy of electromagnetic radiation comes in $h\nu$-sized

“packets”

“bundles”

“discrete units”

The energy of electromagnetic radiation is quantized.

quanta

The Players

- Erwin Schrodinger
- Werner Heisenberg
- Louis Victor De Broglie
- Neils Bohr
- ► Albert Einstein
- Max Planck
- James Clerk Maxwell

Another Mystery in Physics: The Photoelectric Effect

Experiments showed that electrons were ejected from the surface of certain metals exposed to light at a minimum threshold frequency.

Albert Einstein
1905

Accounted for the photoelectric effect by treating light as though it were a stream of particles -- photons.

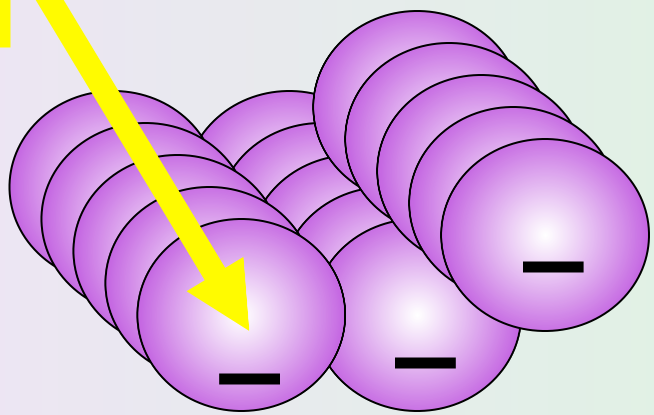
quantization of electromagnetic radiation

$h\nu$ = kinetic energy e^- + binding energy

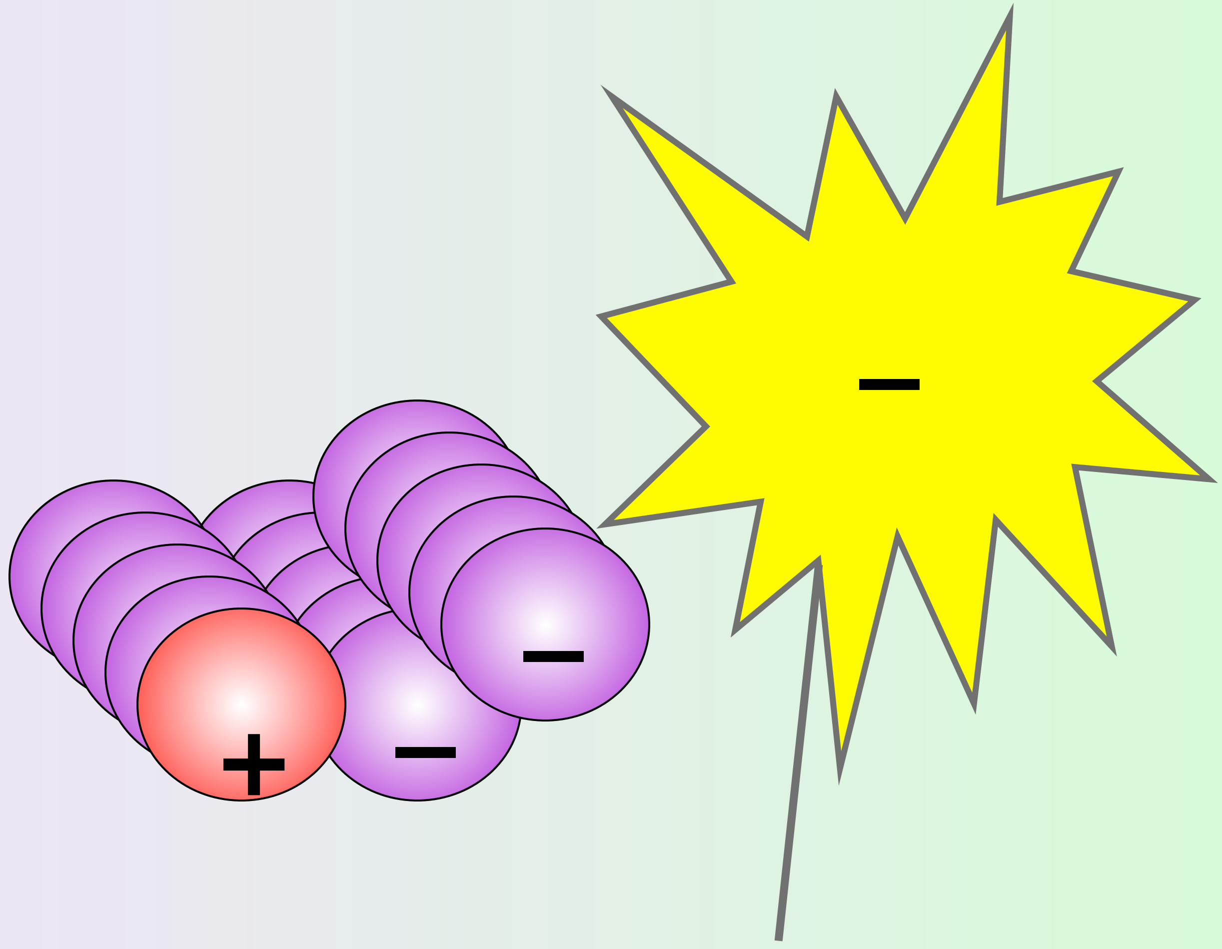
The Photoelectric Effect

“threshold” frequency for ejection of electrons

Photon = $h\nu$



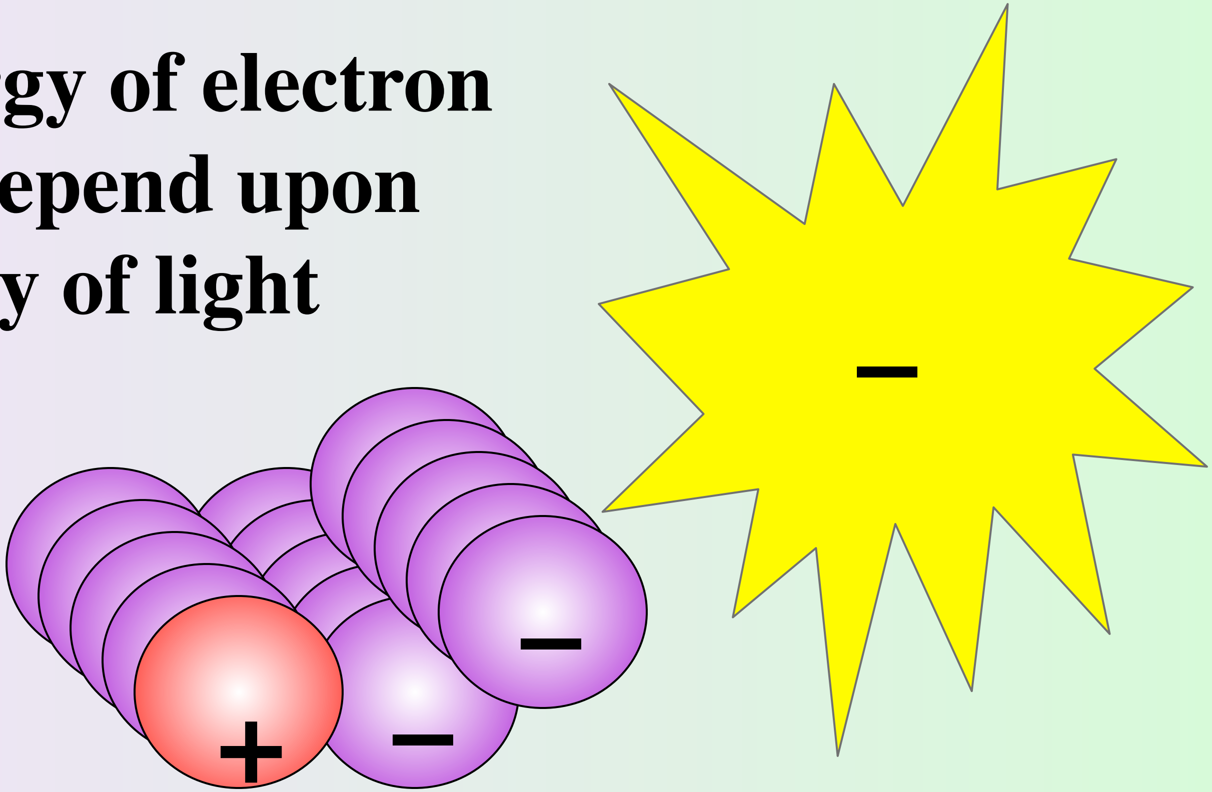
The Photoelectric Effect



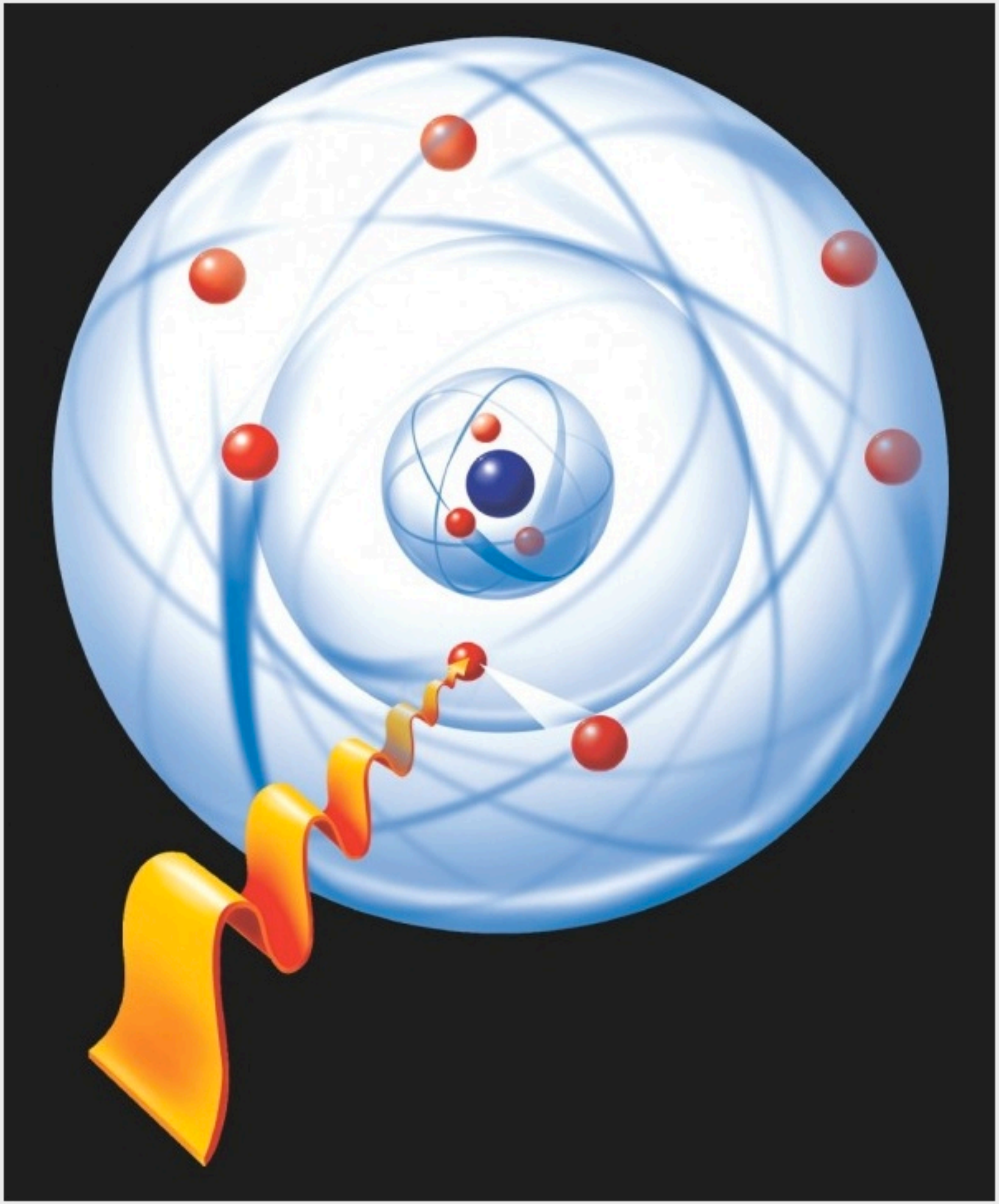
KE = $h\nu$ - BE

The Photoelectric Effect

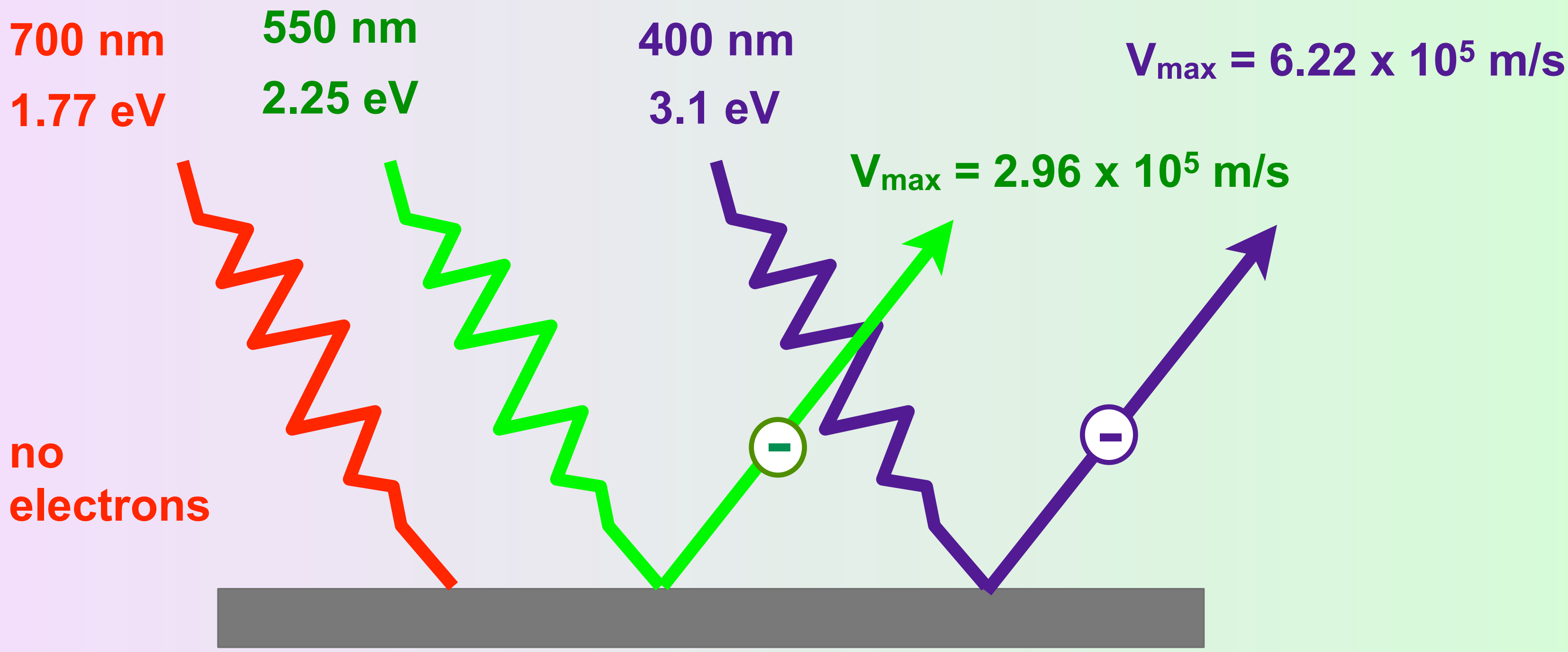
Kinetic energy of electron does not depend upon intensity of light



it depends on the frequency



$$\Delta E = h\nu$$



potassium - 2.0 eV needed to eject an electron

Photoelectric Effect

Mass of a Photon

$$E = h\nu$$

$$E = mc^2$$

$$mc^2 = h\nu$$

$$\lambda = \frac{c}{\nu}$$

$$m = \frac{h \frac{c}{\lambda}}{c^2}$$

$$m = \frac{h}{c\lambda}$$

Mass of a Photon is relativistic

Depending on the experiment:

light behaves either as a wave or as a stream of particles

wave /particle duality

Example

Calculate the energy(in joules)of a photon with a wavelength 5.00×10^4 nm (infrared region).

$$\Delta E = \frac{hc}{\lambda}$$

$$\Delta E = h\nu$$

$$\nu = \frac{c}{\lambda}$$

$$\Delta E = \frac{(6.63 \times 10^{-34}\ \mathrm{J\,.\,s})\ (3.00 \times 10^{8}\ \mathrm{m/s})}{5.00 \times 10^{4}\ \mathrm{nm} \times \dfrac{1 \times 10^{-9}\ \mathrm{m}}{1\ \mathrm{nm}}}$$

$$= 3.98 \times 10^{-21}\ \mathrm{J}$$