
Environmental Sustainability
Clean Energy Sources

Unit 4

Light and Solar Energy

Fossil Fuels Revisited

Traditionally have been a convenient source of energy

All are based on carbon (coal, natural gas, propane, gasoline / petrol

Burning fossil fuels (or any organic compound) produces carbon dioxide

Carbon dioxide is a greenhouse gas – contributes to climate change

Carbon Dioxide as a Greenhouse Gas

Sunlight enters the atmosphere as a range of light – ultraviolet, visible, infrared

Atmospheric CO_2 absorbs infrared light, but lets the others through

UV and visible light are absorbed by the surface, and converted to heat

Heat is released back up as infrared light

Atmospheric CO_2 absorbs this infrared light (heat)

Releases some of it back toward Earth – it cannot escape!

Moving Away from Fossil Fuels

Electric vehicles

Powered by a large, rechargeable battery
But… where does the electricity come from?
Energy cannot be *created* nor destroyed
Must come from another source of energy

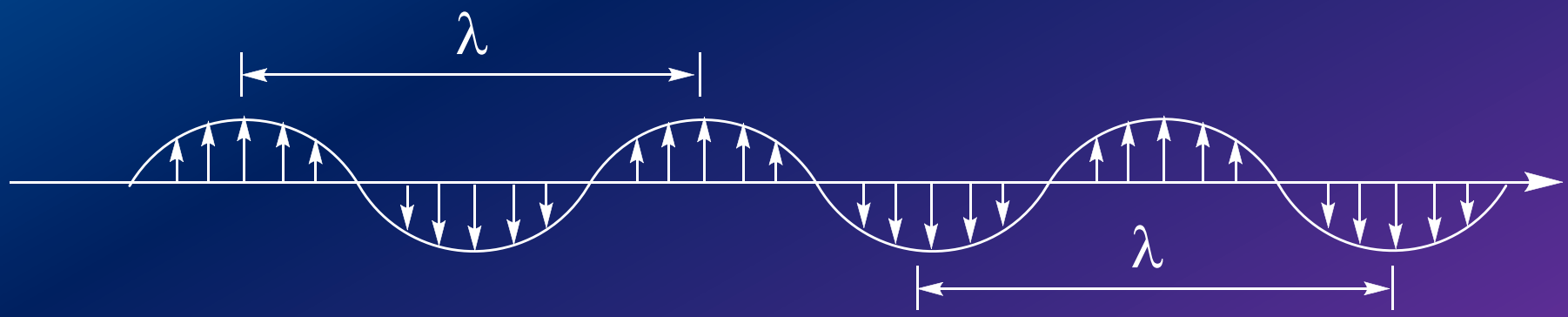
Electricity currently comes mostly from burning coal

So really, CO_2 is still being produced to power an EV


Solar Energy – Energy from the Sun

Electromagnetic Radiation

Perpendicular oscillating electric and magnetic fields.



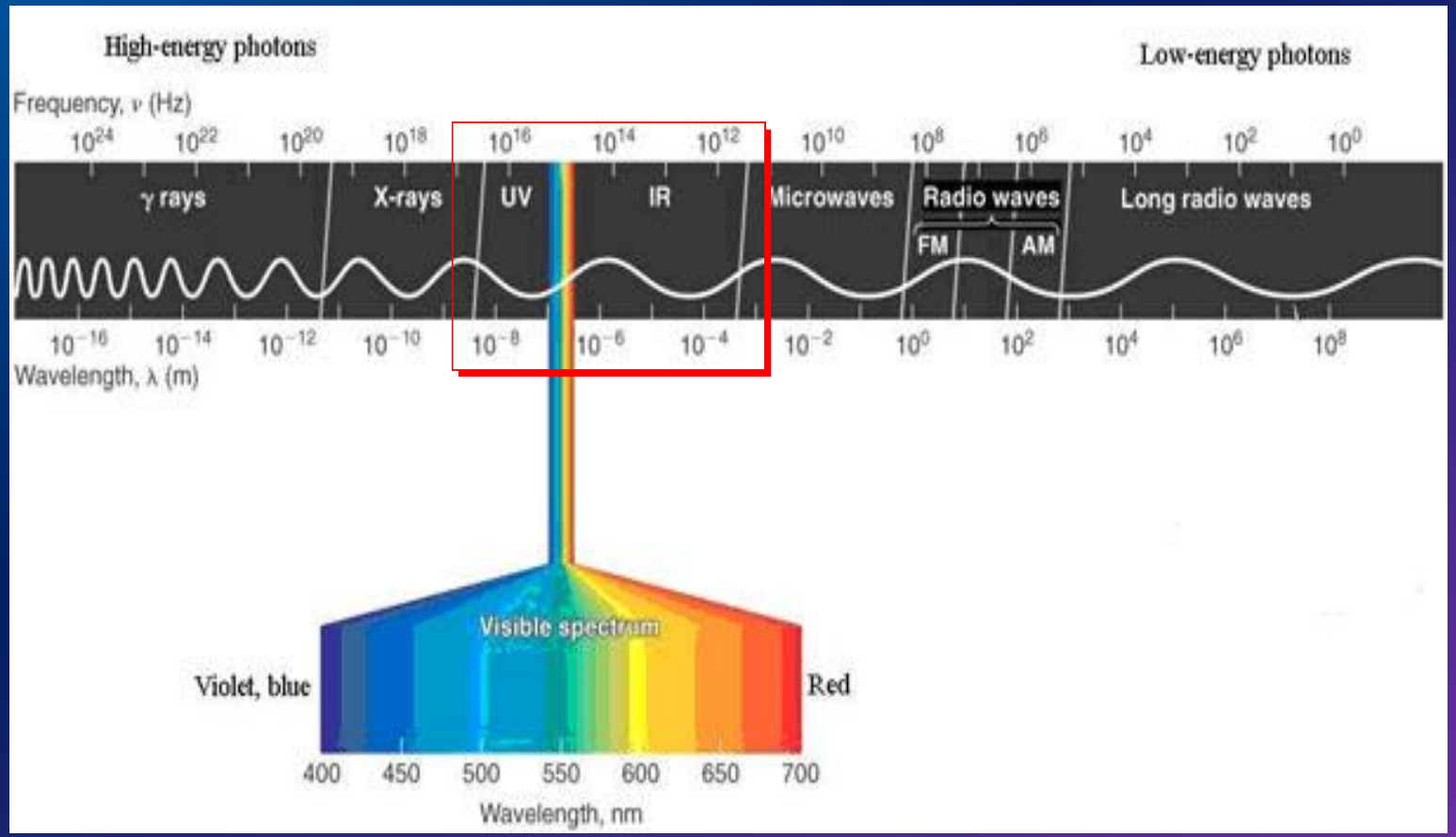
Wavelength (λ): Distance between any two peaks in meters (m)

Velocity (Speed of light, c) = 3.00 x 10^{8} m/s

Frequencey (ν): Number of waves passing through a fixed point per second (s^{-1}, Hz)

$$\nu = c / \lambda$$

The Electromagnetic Spectrum



Visible light only a small portion

Sunlight

Ultraviolet (UV)
Visible
Infrared (IR)

Can Light be Converted to Electricity?

Yes!

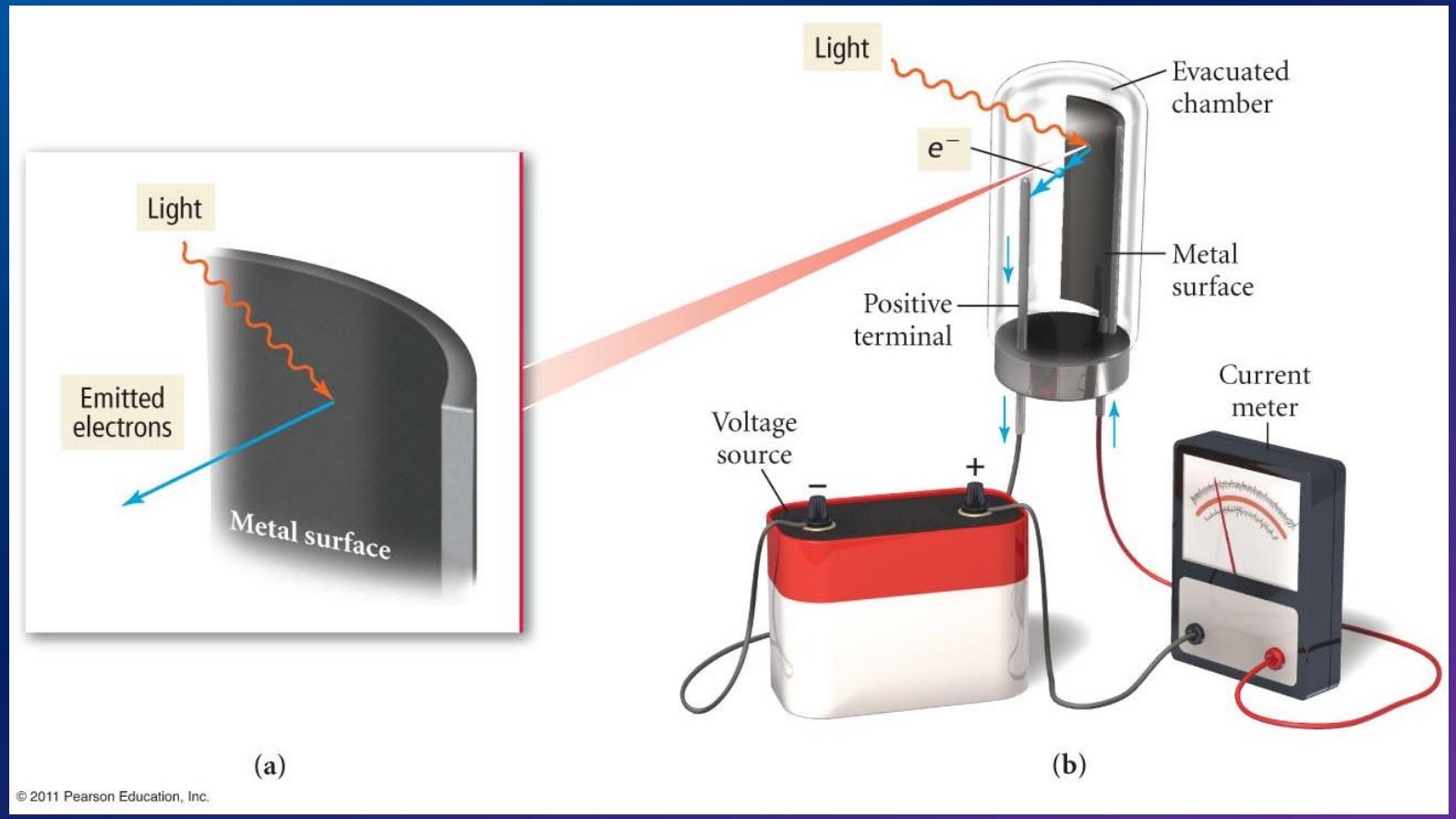
The *Photoelectric Effect*

Observed during the 1800's by physicists studying atomic structure

First step toward our current understanding of where the electrons are

Many metals will emit electrons when light shines on the surface

The Photoelectric Effect



Evacuated tube containing metal sheet

Also an electrode connected to a battery

Shine light on the metal

Current meter shows *increase* in electric current

Conclusion: electrons emitted from the metal find the electrode and join the circuit

The Photoelectric Effect

Intensity / brightness of light had no effect on current (electron emission)

A minimum frequency *was* required to initiate electron emission

Threshold Frequency

Lower then threshold frequency – no electron emission

Greater than or equal to threshold frequency – electrons emitted

Einstein's Explanation

Light / electromagnetic radiation is energy

Delivered in small, discreet packets – *photons*

Energy is directly proportional to frequency

Energy is inversely proportional to wavelength

Add a constant to turn a proportionality to an equality

$$E_{photon} = h\nu = \frac{hc}{\lambda}$$

h = Planck's Constant = 6.626×10^{-34} J · s

Ejected Electrons

One photon at the threshold frequency gives the electron just enough energy for it to escape the atom

Binding Energy, ϕ

When irradiated with a shorter wavelength photon, the electron absorbs more energy than is necessary to escape

This excess energy becomes kinetic energy of the ejected electron

$$E_{photon} = h\nu = \phi + KE$$

Wave Nature of Matter

Louis de Broglie (1892–1987)

Postulated that any particle of matter in motion will have wave-like behavior

Travels with a wavelength that is inversely proportional to its *momentum*

Momentum = mass x velocity (kg m/s)

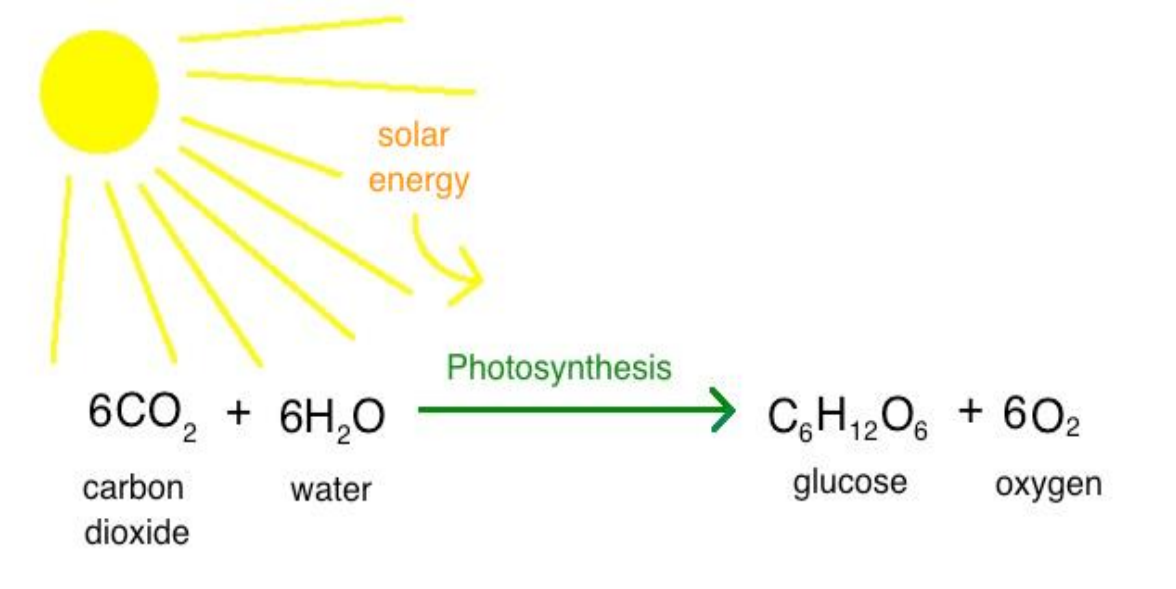
Add Planck's Constant to turn proportionality into an equality

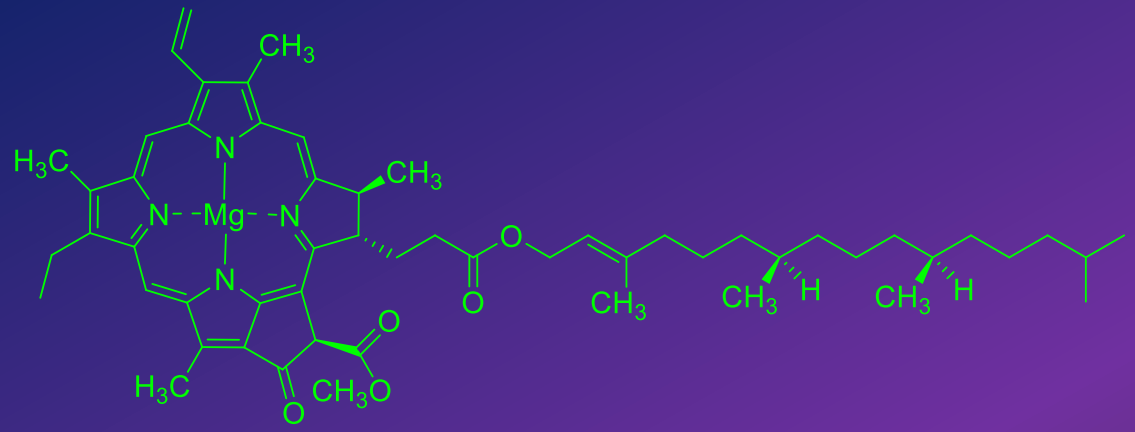
$$\lambda = h/mv$$

h = Planck's Constant = 6.626×10^{-34} J · s

Photosynthesis

Nature’s use of the photoelectric effect



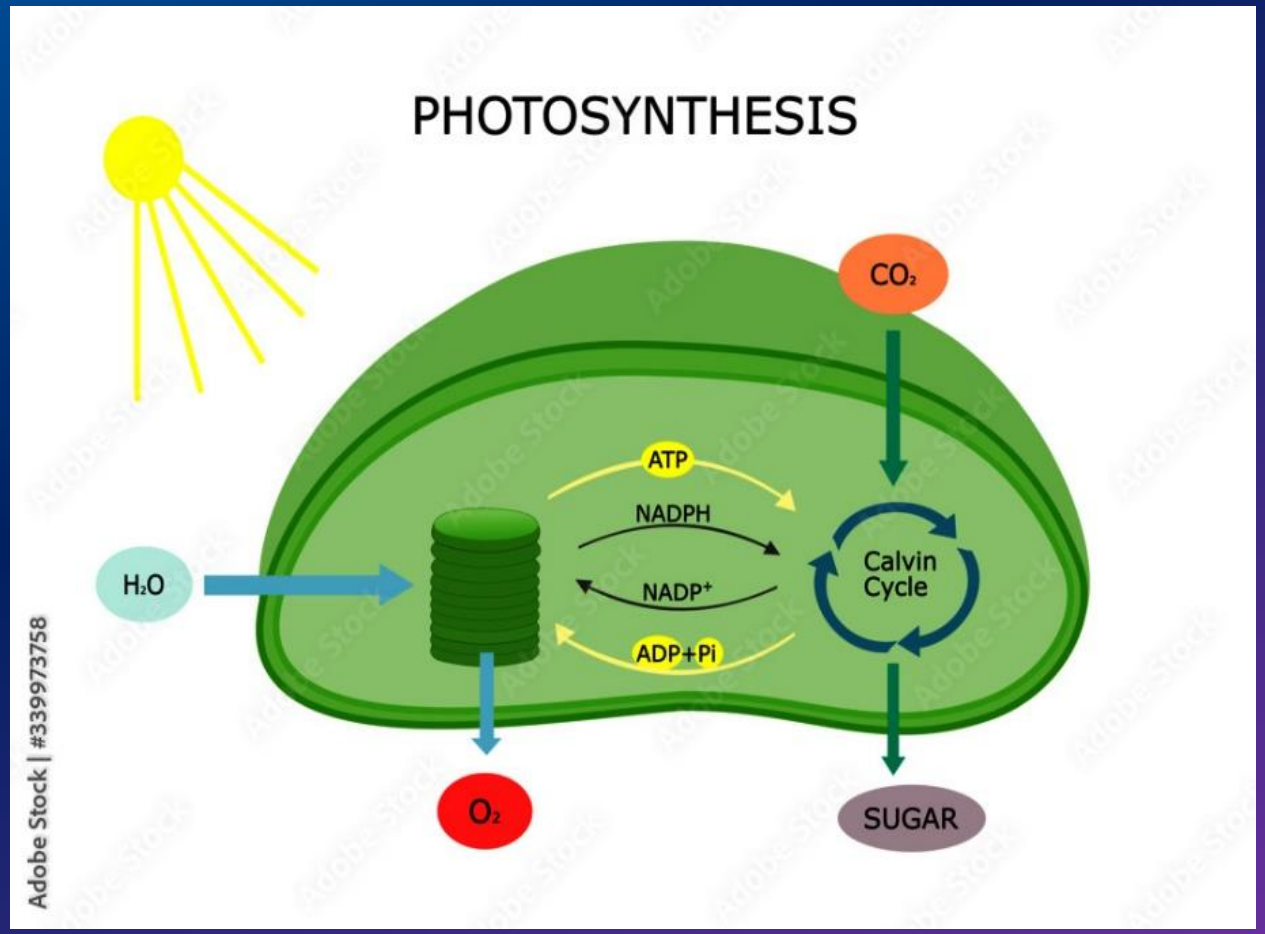


Chlorophyll A
Green

Green plants and algae use light energy from the sun to convert carbon dioxide and water into glucose and oxygen

Photosynthesis

Takes place in the *chloroplast* of a green plant cell



Stacked *thylakoids* contain the chlorophyll

Chlorophyll absorbs sunlight – ejects electrons

Electrons used to convert ADP into ATP

Electrons reduce $NADP^+$ to NADPH

ATP and NADH used to convert CO_2 ultimately to glucose

Solar Panels Convert Light to Electricity

Practical application of the photoelectric effect

Microcrystalline silicon “wafers” used as *photovoltaic cells*

Threshold frequency = 2.73 x 10^{14} Hz
Infrared region of EMS

Sunlight – Ultraviolet, visible, and infrared regions of EMS

PV cells linked together into *modules*

Modules linked together to form panels