

Quantum physics

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

This handout covers selected HL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: read the stated quantities and units, and use arithmetic and the model conditions below.

The examples are original and fictional: they are not real measurements or real student investigations.

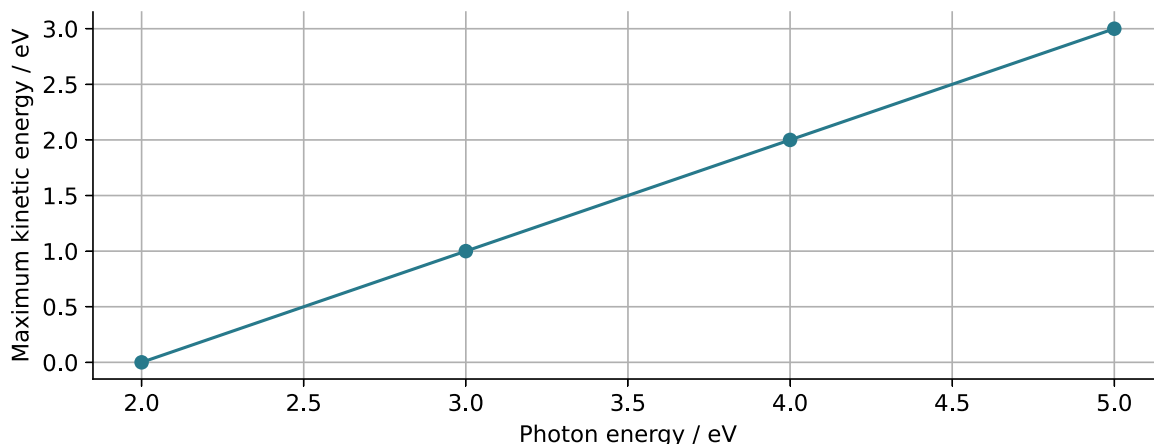
Photons and the photoelectric effect

■ What would explain this observation?

- Bright low-frequency light can fail to eject electrons while dim higher-frequency light succeeds. **Photon** energy depends on frequency, not intensity alone.

■ Build the model

- A photon has energy proportional to frequency.
- The **work function** is the minimum energy needed to release an electron from a surface.
- Above threshold, excess photon energy can become electron kinetic energy.
- photon: A quantum of electromagnetic radiation.
- work function: Minimum surface energy needed to release an electron.



$$E_k(\max) = hf - \varphi: \text{no emission below } 2.0 \text{ eV, the work function}$$

■ Choose evidence that can test it

- Use photon energy = Planck constant $\times$ frequency.
- Maximum kinetic energy = photon energy - work function.
- Increasing intensity at fixed frequency increases photon arrival rate, not individual photon energy.

In the lab: Read axes carefully on a stopping-potential or kinetic-energy graph. Identify threshold frequency from the zero-energy intercept. State the metal and experimental conditions because work function is material-specific.

■ Work from known quantities

- Known: photon energy is 5.0 electronvolts and work function is 2.0 electronvolts.
- Maximum kinetic energy = photon energy - work function = 5.0 - 2.0 = 3.0 electronvolts.
- A 1.5 electronvolt photon cannot cause emission from that surface in this model.

Your turn: Photon energy is 4.8 eV and work function 2.1 eV. Find maximum kinetic energy.

■ Check the conclusion and its limits

- Electrons do not accumulate many sub-threshold photons in the elementary single-photon model.
- Do not confuse photon number with photon energy.

Not true: Doubling light intensity doubles each photon energy at fixed frequency. Intensity is the number of photons arriving per second; photon energy is set by frequency alone ($E = hf$). Doubling intensity doubles the electron count, not each electron's energy - exactly what the photoelectric equation shows.

Key:

- A photon has energy proportional to frequency.
- Use photon energy = Planck constant $\times$ frequency.
- Watch for: electrons do not accumulate many sub-threshold photons in the elementary single-photon model.

■ Write from a maximum kinetic energy of 3.6 electronvolts

- A photon has energy 6.0 electronvolts and the work function is 2.4 electronvolts.
- Find the maximum kinetic energy. Doubling the intensity does not double each photon's energy.

■ **Write from a threshold read**

- Work function 2.0 eV; incident photons of 3.0 eV.
- Maximum electron energy = $3.0 - 2.0 = 1.0 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$ – below threshold no intensity helps; above it, intensity sets the current while frequency sets the energy.

■ **Write from a stopping voltage**

- The fastest electrons are just stopped by 1.5 V.
- Their maximum kinetic energy is 1.5 eV – the stopping voltage measures electron energy directly, one volt per electronvolt.