

Exercise walk-through

21.1

Photons and the photoelectric effect

International Baccalaureate · IB Diploma · Physics · HL

21.1 Photons and the photoelectric effect

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS photon • work function

Objective

Photons and the photoelectric effect. Original classroom practice for IB HL; not an official IB paper.

1 Key knowledge and worked examples

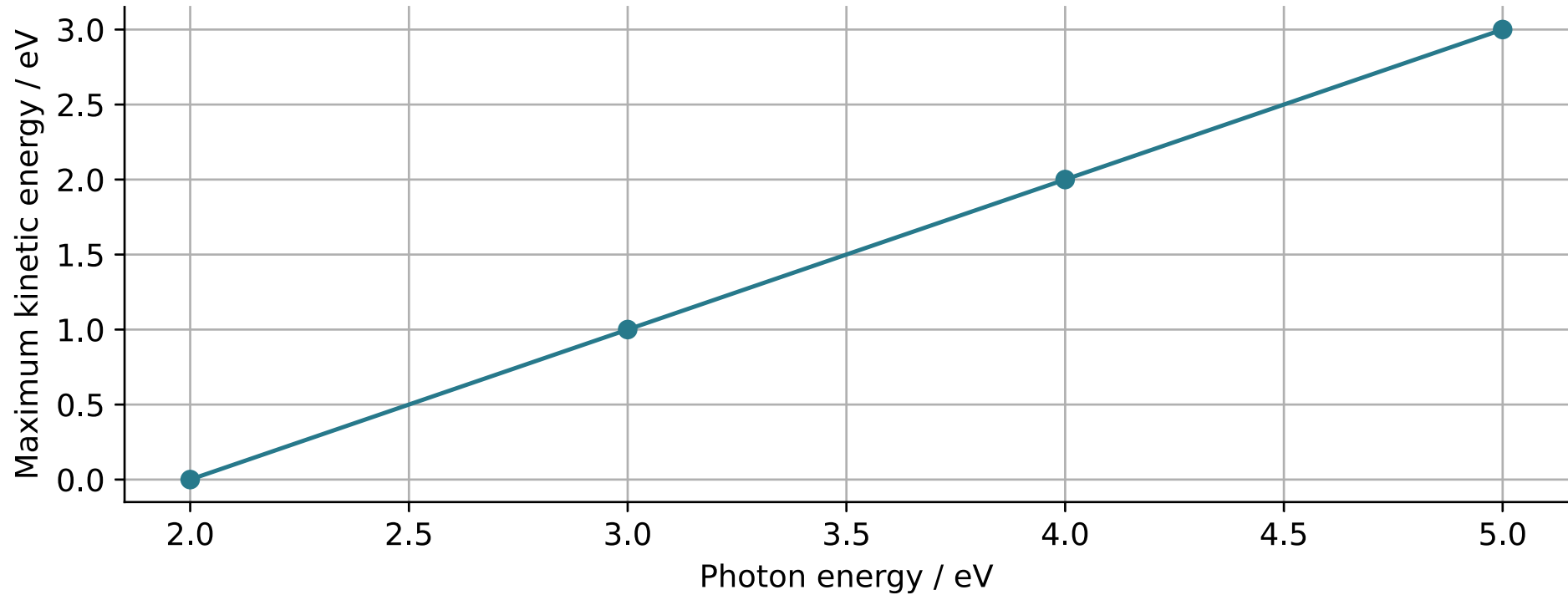
■ What would explain this observation?

- 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.



■ 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. In-

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 pho-

ton's energy.

Exercises 2.1·2.2

2.1 At fixed above-threshold frequency, increasing intensity mainly increases what?
Choose one answer.

- **A** Photon energy
- **B** Work function
- **C** The number of emitted electrons per time

[1]

2.2 Photon energy is 4.8 eV and work function 2.1 eV. Find maximum kinetic energy.
Show the relation, substitution and units.

[2]

Exercises 2.1·2.2

2.1 At fixed above-threshold frequency, increasing intensity mainly increases what? Choose one answer.

- **A** Photon energy
- **B** Work function
- **C** The number of emitted electrons per time

[1]

2.1 C Photon energy depends only on frequency ($E = hf$), so raising intensity at fixed frequency adds more photons, each unchanged. More photons above threshold liberate more electrons per second; the work function is a property of the surface.

2.2 Photon energy is 4.8 eV and work function 2.1 eV. Find maximum kinetic energy. Show the relation, substitution and units.

[2]

2.2 $K_{\max} = \text{photon energy} - \text{work function} = 4.8 - 2.1 = 2.7 \text{ eV}.$

Exercises 2.3-3.1

2.3 Decide whether this claim is true and justify: Doubling light intensity doubles each photon energy at fixed frequency. [2]

2.4 A quantum of electromagnetic radiation: write the technical term. [1]

3.1 A surface has work function 2.5 eV. Compare 2.0 and 4.0 eV photons and predict what doubling intensity changes in the one-photon model. [4]

Exercises 2.3-3.1

2.3 Decide whether this claim is true and justify: Doubling light intensity doubles each photon energy at fixed frequency. [2]

2.3 False. 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.

2.4 A quantum of electromagnetic radiation: write the technical term. [1]

2.4 photon. photon means A quantum of electromagnetic radiation.

3.1 A surface has work function 2.5 eV. Compare 2.0 and 4.0 eV photons and predict what doubling intensity changes in the one-photon model. [4]

3.1 2.0 eV cannot cause emission; 4.0 eV gives maximum kinetic energy 1.5 eV. Above threshold, greater intensity supplies more photons, not more energy per photon. It does not raise $K_{\max}$.