

Photons, work functions and matter waves

AP Physics 2 (algebra-based) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train you to move between photon energy, wavelength and frequency, to analyse photoelectric data and to use the de Broglie relation. They climb from one-step conversions to multi-part AP-style reasoning and graph analysis. They suit AP Physics 2 unit 15 and the quantum sections of A level courses.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 15

Problem 1 Photon energy from frequency (easy)

Aarav in Pune uses a green laser pointer of frequency 5.0×10^{14} Hz.

1. Calculate the energy of one photon in joules.
2. Convert the answer to electronvolts.

Problem 2 Converting energy units (easy)

Convert the following.

1. 3.20 eV to joules.
2. 2.0×10^{-19} J to electronvolts.

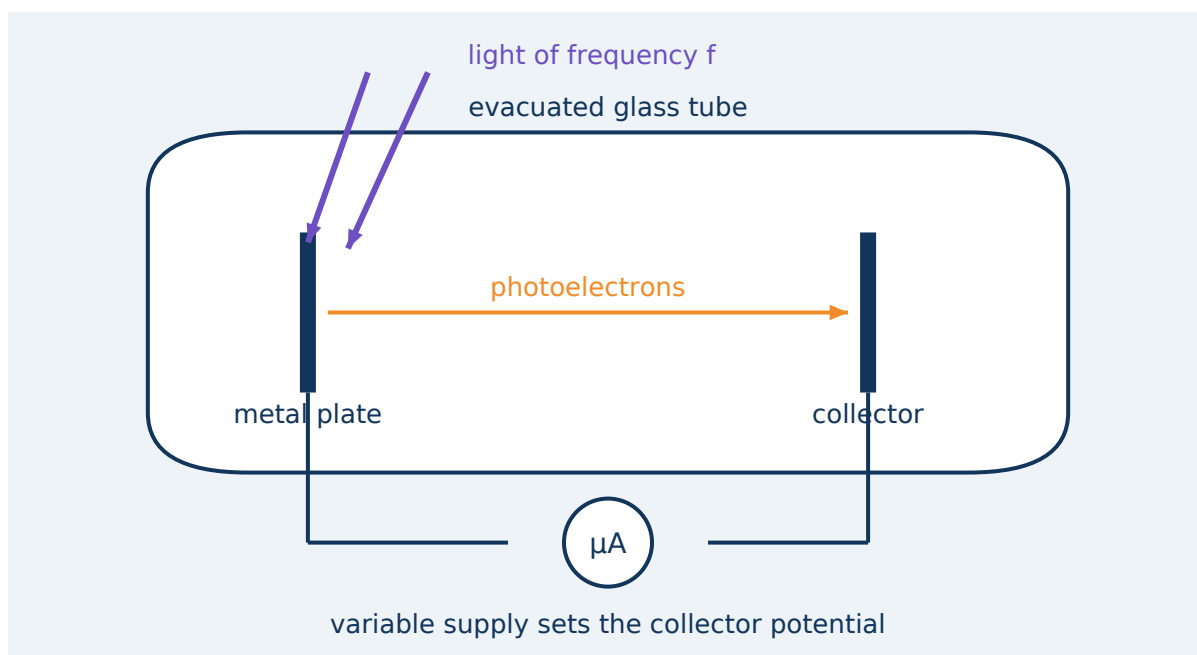
Problem 3 Energy from wavelength (easy)

Use $hc = 1240$ eV·nm.

1. Calculate the energy in eV of a photon of wavelength 620 nm.
2. State whether a photon of wavelength 310 nm has more or less energy, and by what factor.

Problem 4 Bright light below the threshold (easy)

Chiamaka in Lagos shines a very bright red lamp on a zinc plate in a photoelectric tube, and the microammeter reads zero. She then uses a dim ultraviolet lamp and the meter shows a current.



Photoelectric apparatus: the microammeter shows the current of ejected electrons.

1. Explain why bright red light ejects no electrons.
2. Explain why dim ultraviolet light does.

Problem 5 Threshold of a metal (easy)

A metal has a work function of 2.10 eV. Use $hc = 1240 \text{ eV}\cdot\text{nm}$ and $c = 3.00 \times 10^8 \text{ m/s}$.

1. Calculate the threshold wavelength.
2. Calculate the threshold frequency.

Problem 6 Maximum kinetic energy (easy)

Light of wavelength 350 nm falls on a metal of work function 2.30 eV.

1. Calculate the photon energy.
2. Calculate the maximum kinetic energy of the photoelectrons.
3. State the stopping potential.

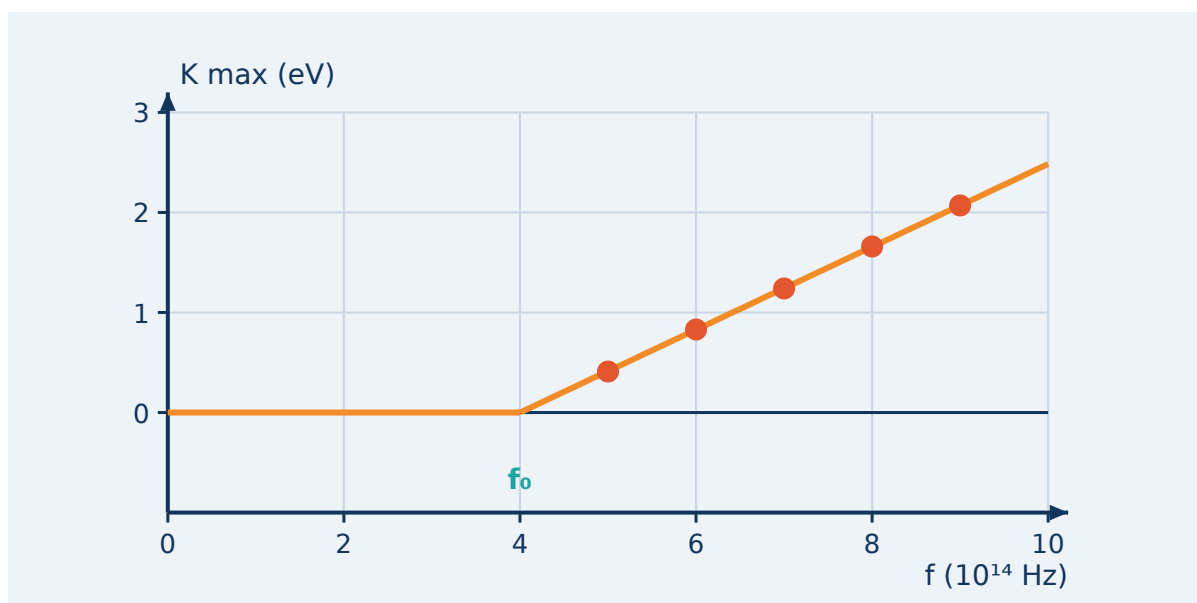
Problem 7 Wavelength of a cricket ball (medium)

A cricket ball of mass 0.16 kg moves at 30 m/s.

1. Calculate its momentum.
2. Calculate its de Broglie wavelength.
3. Explain why wave effects are never seen for the ball.

Problem 8 Reading a K_{max} graph (medium)

Wanjiru in Nairobi measures K_{max} for different frequencies. The straight line in the graph passes through the points shown.



Maximum kinetic energy against frequency: the line starts at the threshold frequency f_0 .

1. Read the threshold frequency.
2. Calculate the gradient in $\text{eV}\cdot\text{s}$.
3. Convert the gradient to $\text{J}\cdot\text{s}$ and compare with the Planck constant.
4. Find the work function in eV .

Problem 9 Photons per second (medium)

A laser pointer has a power of 5.0 mW and a wavelength of 532 nm.

1. Calculate the energy of one photon in joules.
2. Calculate the number of photons emitted each second.

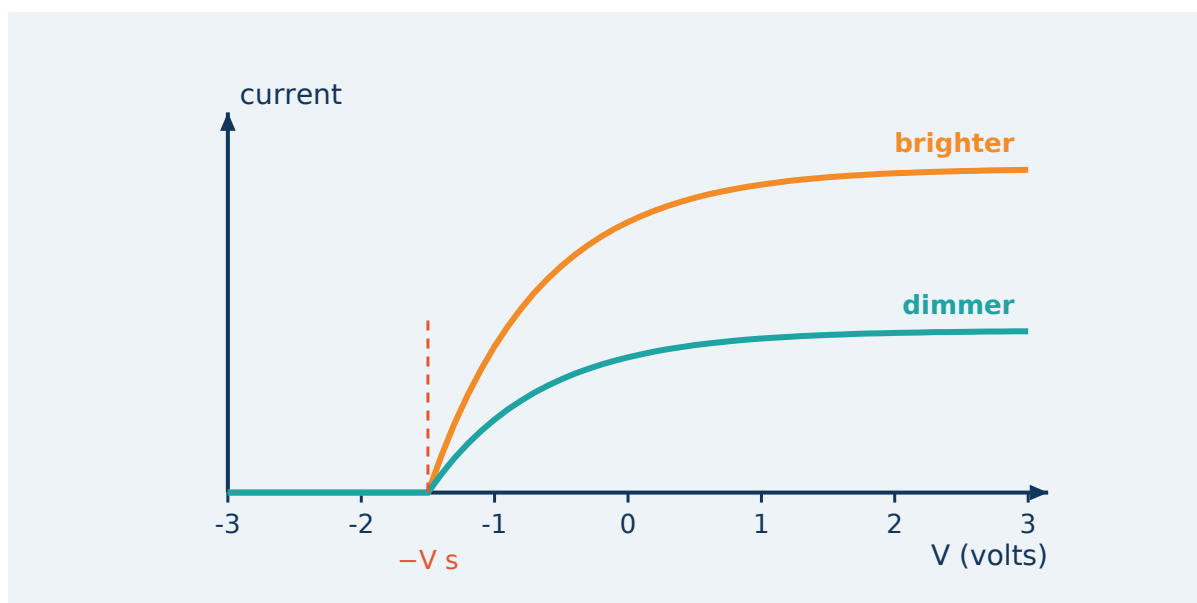
Problem 10 Momentum of an electron wave (medium)

An electron has a de Broglie wavelength of 0.20 nm. Take $m = 9.11 \times 10^{-31} \text{ kg}$.

1. Calculate its momentum.
2. Calculate its speed.
3. Calculate its kinetic energy in eV .

Problem 11 Predict the effect of changes (medium)

A photoelectric tube is illuminated by light above the threshold frequency. Predict what happens to (a) the current, (b) the maximum kinetic energy and (c) the stopping potential in each case.



Current against potential: both curves reach zero at the same stopping potential.

1. The intensity is doubled at the same frequency.
2. The frequency is increased at the same intensity.
3. The metal is replaced with one of larger work function.

Problem 12 Which light ejects electrons? (medium)

Metal X has a work function of 2.0 eV. Ultraviolet light of 250 nm and red light of 700 nm both shine on it.

1. Calculate the photon energy of each.
2. Decide which colour ejects electrons.
3. Calculate the maximum kinetic energy of the ejected electrons.

Problem 13 Stopping potential data (medium)

Bilal in Lahore measures the stopping potential V_s for four wavelengths on a clean metal.

λ (nm)	450	400	350	300
V_s (V)	0.56	0.90	1.34	1.93

1. Calculate the photon energy in eV for each wavelength.
2. Calculate $E - \phi$ in eV for each.
3. Use the results to state the work function.

Problem 14 Spot the error (medium)

A student writes: "If I make red light brighter and brighter it will eventually eject electrons from a metal whose threshold is in the ultraviolet, because the beam carries more energy."

1. Identify the error.

2. Rewrite the statement correctly.

Problem 15 Sunscreen and bond breaking (medium)

A bond in a skin molecule needs 3.8 eV to break. Use $hc = 1240 \text{ eV}\cdot\text{nm}$.

1. Calculate the longest wavelength of a photon that can break the bond.
2. Decide whether a 300 nm photon and a 600 nm photon can break it.

Problem 16 Unknown frequency from a stopping potential (hard)

Light falls on a metal of work function 2.40 eV and the stopping potential is 1.10 V.

1. Calculate the photon energy in eV.
2. Calculate the frequency of the light.
3. Calculate its wavelength.

Problem 17 Electrons through a voltage (hard)

Emma in Leeds accelerates electrons through 400 V.

1. Calculate the kinetic energy in joules.
2. Calculate the momentum.
3. Calculate the de Broglie wavelength.
4. Explain why the electrons could be diffracted by a crystal with atomic spacing 0.20 nm.

Problem 18 Single electrons through slits (hard)

Electrons of wavelength $5.0 \times 10^{-11} \text{ m}$ pass one at a time through two slits $1.0 \mu\text{m}$ apart toward a detector 0.50 m away. Spots build up on the screen.

1. Describe the pattern that emerges after many electrons have arrived.
2. Calculate the spacing between neighbouring maxima.
3. Explain what the experiment shows about the nature of electrons.

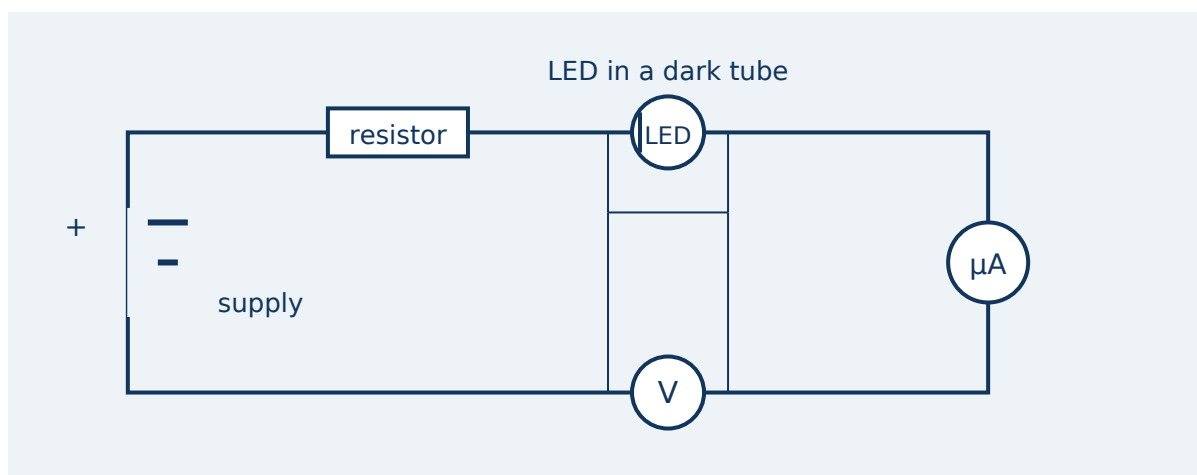
Problem 19 Photon against electron (hard)

A photon and an electron both have a wavelength of 0.10 nm.

1. Show that they have the same momentum and calculate it.
2. Calculate the photon energy in keV.
3. Calculate the electron kinetic energy in eV.
4. Compare the two energies and explain the difference.

Problem 20 Measure h with LEDs (hard)

Design a method to find h using LEDs. A red LED (630 nm) begins to glow at 1.96 V and a blue LED (470 nm) at 2.62 V.



Circuit: the voltmeter is across the LED and the resistor protects it.

1. Explain what is measured and what graph to plot.
2. Use the two data points to find the gradient in $V \cdot m$.
3. Calculate h from the gradient.