

Photon energy, work function and matter waves

Physics grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train you to calculate photon energies, apply Einstein's photoelectric equation, read graphs of kinetic energy and photocurrent, and use the de Broglie wavelength. They move from single substitutions to multi-step problems with photocells and electron diffraction.

They suit A Level, IB Physics, CBSE Class 12 and WAEC senior students. Use $h = 6.63 \times 10^{-34} \text{ J s}$, $c = 3.00 \times 10^8 \text{ m/s}$, $e = 1.60 \times 10^{-19} \text{ C}$ and electron mass $9.11 \times 10^{-31} \text{ kg}$.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB E.2

Problem 1 Energy from frequency (easy)

Light of frequency $6.0 \times 10^{14} \text{ Hz}$ falls on a surface.

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

Problem 2 Laser pointer photon (easy)

A red laser pointer used by Wanjiru in Nairobi emits light of wavelength 650 nm.

1. Calculate the energy of one photon in joules and in eV.

Problem 3 Frequency of ultraviolet (easy)

Ultraviolet light has a wavelength of 250 nm.

1. Calculate its frequency.

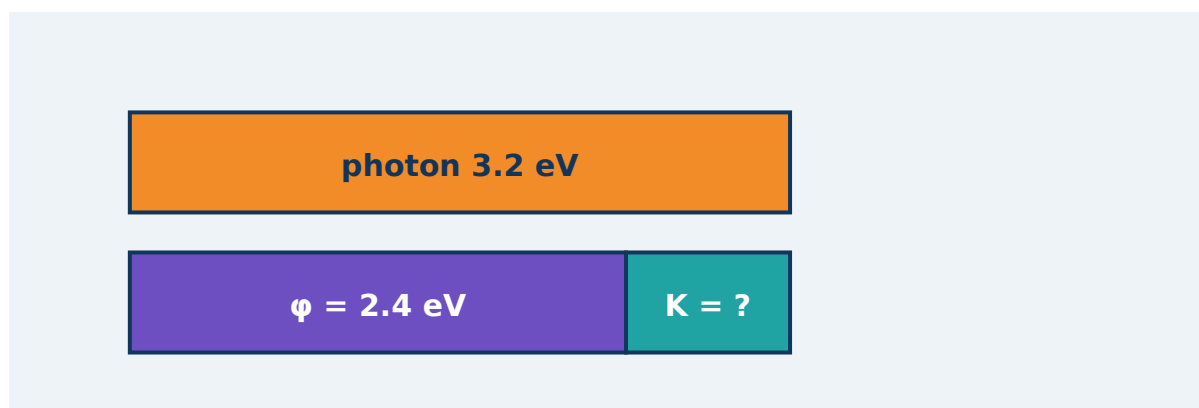
Problem 4 Caesium threshold (easy)

Caesium has a work function of 2.1 eV.

1. Convert it to joules.
2. Calculate the threshold frequency.

Problem 5 Photon sharing its energy (easy)

Photons of energy 3.2 eV fall on a metal of work function 2.4 eV.



Photon energy shared between work function and kinetic energy.

1. Calculate the maximum kinetic energy of the electrons in eV.
2. Convert this to joules.

Problem 6 Bright red light (easy)

Bright red light does not release electrons from a zinc plate, but a weak ultraviolet lamp does.

1. Explain why using the idea of photons.

Problem 7 Stopping potential (easy)

The fastest photoelectrons from a metal have a kinetic energy of $2.4 \times 10^{-19} \text{ J}$.

1. Calculate the stopping potential.

Problem 8 Green laser photons (medium)

A green laser of wavelength 532 nm has an output power of 5.0 mW.

1. Calculate the energy of one photon.
2. Calculate the number of photons emitted per second.

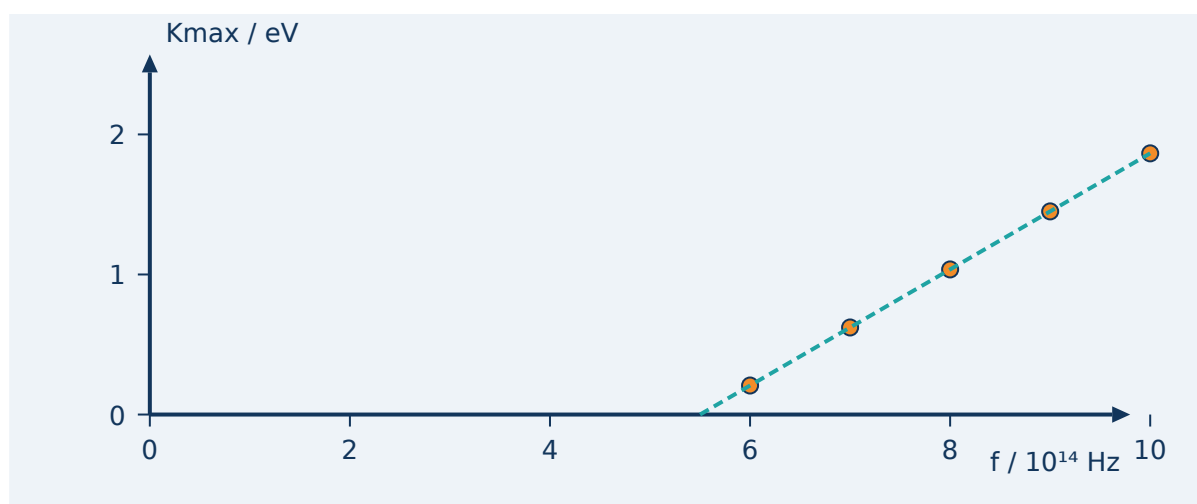
Problem 9 Potassium test (medium)

Emma in Leeds shines light on potassium, which has a work function of 2.3 eV.

1. Calculate the photon energy at 500 nm and at 600 nm in eV.
2. State which wavelength ejects electrons and calculate K_{max} .

Problem 10 Reading a K_{max} graph (medium)

The graph shows the maximum kinetic energy of photoelectrons from a metal for five frequencies.



Kmax against frequency for one metal.

1. Read the threshold frequency.
2. Find the gradient between f_0 and the point $(10 \times 10^{14} \text{ Hz}, 1.87 \text{ eV})$.
3. Use the gradient and the threshold frequency to find the work function in eV.

Problem 11 Doubling the brightness (medium)

A photocell is lit by monochromatic light above the threshold frequency. The intensity of the light is doubled with the frequency unchanged.

1. Predict what happens to the photocurrent.
2. Predict what happens to K_{max} .
3. Explain both answers.

Problem 12 Finding the work function (medium)

Light of wavelength 300 nm falls on a metal. The stopping potential is 1.74 V.

1. Calculate the photon energy in eV.
2. Calculate the work function in eV.
3. Calculate the threshold wavelength.

Problem 13 Wavelength of an electron (medium)

An electron moves at $2.0 \times 10^6 \text{ m/s}$.

1. Calculate its de Broglie wavelength.
2. Compare it with an atomic spacing of about 0.2 nm.

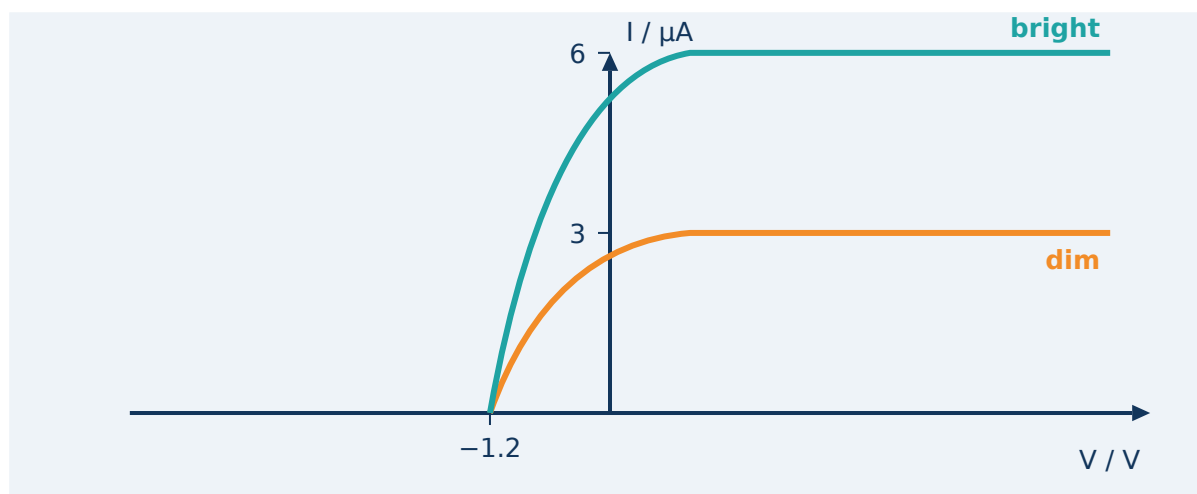
Problem 14 Cricket ball wavelength (medium)

Aarav in Pune watches a bowler send a 0.16 kg cricket ball at 38 m/s.

1. Calculate the de Broglie wavelength of the ball.
2. Explain why wave behaviour is not seen.

Problem 15 Current-voltage graph (medium)

The graph shows photocurrent against collector voltage for the same light at two brightnesses.



Photocurrent against voltage for two intensities of the same light.

1. Read the stopping potential and state $K_{\max}$ in eV.
2. Compare the saturation currents.
3. Explain why the stopping potential is the same for both curves.

Problem 16 Photon against electron (hard)

An X-ray photon and an electron each have a wavelength of 0.10 nm.

1. Calculate the energy of the photon in joules and in keV.
2. Calculate the momentum and the kinetic energy of the electron in eV.
3. Explain why electrons are better than X-rays for some investigations.

Problem 17 Electron diffraction (hard)

Electrons are accelerated from rest through 150 V and directed at a crystal whose planes are 0.215 nm apart.

1. Calculate the electron's momentum.
2. Calculate its de Broglie wavelength.
3. Calculate the angle of the first-order diffraction maximum from $n\lambda = d \sin \theta$.

Problem 18 Two wavelengths (hard)

A metal has work function 2.9 eV. It is lit with light of wavelength 400 nm and then 300 nm.

1. Calculate $K_{\max}$ and the stopping potential for each wavelength.
2. Calculate the speed of the fastest electrons for 300 nm.
3. Calculate the threshold wavelength.

Problem 19 Photocell current (hard)

Light of wavelength 400 nm and power 2.0 mW falls on the cathode of a photocell. Only 1.0 % of the photons each eject one electron that reaches the anode.

1. Calculate the number of photons arriving each second.
2. Calculate the number of electrons collected each second.
3. Calculate the photocurrent.

Problem 20 Spot the errors (hard)

A student writes: "An electron at 3.0×10^6 m/s has $\lambda = h/(mv) = 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 3.0 \times 10^6) = 2.4 \times 10^{-9}$ m. Doubling the light intensity doubles $K_{\max}$."

1. Find and correct the error in the calculation.
2. Correct the statement about intensity.
3. Explain how an order-of-magnitude estimate would have caught the first error.