FARLabs Photoelectric Effect Experiments Curriculum Relevance

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Photoelectric Effect Experiment Details:

Experiments	Year Level Relevance	Subjects	Class Sizes
Photoelectric Effect	12	Physics	16 students (8 groups of 2)

Photoelectric Effect Australian Curriculum Relevance

Australian Curriculum Education Level	Curriculum Learning Outcomes and Examples

Senior School Science Australian Curriculum – Physics Unit 4: Revolutions in modern physics	**Learning Outcomes:**
	• understand how the quantum theory of light and matter explains blackbody radiation, the photoelectric effect, and atomic emission and absorption spectra
	• understand how models and theories have developed over time, and the ways in which physical science knowledge and associated technologies interact with social, economic, cultural and ethical considerations
	• use science inquiry skills to design, conduct, analyse and evaluate investigations into frames of reference, diffraction, black body and atomic emission spectra, the photoelectric effect, and photonic devices, and to communicate methods and findings
	• evaluate the experimental evidence that supports the theory of relativity, wave-particle duality, the Bohr model of the atom, the Standard Model, and the Big Bang theory
	• communicate physics understanding using qualitative and quantitative representations in appropriate modes and genres.
	
	Examples in context (Quantum Theory):
	• Development of the quantum model
	    • Max Planck and Einstein were the first to describe light and energy as being quantised, a finding that led to light being described as spatially quantised photons of energy. The Bohr model of the atom was built on this quantised description of light energy and Rutherford's nuclear model. The Bohr model was a quantum-based modification to Rutherford's model and was rapidly accepted due to its ability to explain the emission lines of atomic hydrogen. Prior to Bohr's model, the Rydberg formula describing the wavelengths of spectral lines of many chemical elements was known but could not be explained. A more elaborate quantum mechanical model of the atom, however, was required to explain other observations made about atoms. The quantum mechanical model of the atom uses quantum theory and describes electron orbitals that can be used to calculate the probability of finding an electron at a specific point (ACSPH123).
	
	• Mathematical representations and relationships
	    • Atomic phenomena and the interaction of light with matter indicate that states of matter and energy are quantised into discrete values (ACSPH135)
	    • On the atomic level, electromagnetic radiation is emitted or absorbed in discrete packets called photons; the energy of a photon is proportional to its frequency; and the constant of proportionality, Planck's constant, can be determined experimentally (for example, from the photoelectric effect or the threshold voltage of coloured LEDs) (ACSPH136)

	• A wide range of phenomena, including black body radiation and the photoelectric effect, are explained using the concept of light quanta (ACSPH137) • Atoms of an element emit and absorb specific wavelengths of light that are unique to that element; this is the basis of spectral analysis (ACSPH138) • The Bohr model of the hydrogen atom integrates light quanta and atomic energy states to explain the specific wavelengths in the hydrogen spectrum and in the spectra of other simple atoms; the Bohr model enables line spectra to be correlated with atomic energy-level diagrams (ACSPH139) • On the atomic level, energy and matter exhibit the characteristics of both waves and particles (for example, Young's double slit experiment is explained with a wave model but produces the same interference pattern when one photon at a time is passed through the slits) (ACSPH140) $E = hf$ E = energy of photon, f = frequency, h = $(6.626 \times 10^{-34}\ J\ s)$ $\lambda_{max} = \frac{b}{T}$ λ_{max} = peak wavelength, T = absolute temperature, b = Wien's displacement constant $(2.898 \times 10^{-3}\ m\ K)$ $E_k = hf - W$ E_k = Ek= kinetic energy of photoelectron, hf = energy of incident photon, W = work function of the material $\lambda = \frac{h}{p}$ λ = wavelength associated with particle, p = momentum of particle, h = Planck's constant $(6.626 \times 10^{-34}\ J\ s)$ $n\lambda = 2\pi r$ n = an integer 1, 2, 3, 4… , λ =wavelength of electron, r = orbital radius of electron $mvr = \frac{nh}{2\pi}$ m = mass of electron, v = velocity of electron, r = orbital radius of electron, n = an integer 1, 2, 3, 4, etc., h = Planck's constant $(6.626 \times 10^{-34}\ J\ s)$ $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ λ = wavelength of spectral line, n_i = principal quantum number of initial electron state, n_f = nf= principal quantum number of final electron state, R = Rydberg's constant $(1.097 \times 10^{7}\ m^{-1})$ **Codes:** ▪ Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power (ACSPH123)

Photoelectric Effect Victorian Certificate of Education (VCE) Curriculum Relevance

VCE Education Level	Curriculum Learning Outcomes and Examples

VCE - Physics Unit 4: How can two contradictory models explain both light and matter?	**Area of Study 2 (Outcome 2): How are light and matter similar?**
	
	Key Knowledge:
	• Behaviour of light
	    • analyse the photoelectric effect with reference to:
	        • evidence for the particle-like nature of light
	        • experimental data in the form of graphs of photocurrent versus electrode potential, and of kinetic energy of electrons versus frequency
	        • kinetic energy of emitted photoelectrons: $E_{k\,max} = hf - \phi$, using energy units of joule and electron-volt
	        • effects of intensity of incident irradiation on the emission of photoelectrons
	    • describe the limitation of the wave model of light in explaining experimental results related to the photoelectric effect.
	• Similarities between light and matter
	    • compare the momentum of photons and of matter of the same wavelength including calculations.
	    • explain the production of atomic absorption and emission line spectra, including those from metal vapour lamps
	    • interpret spectra and calculate the energy of absorbed or emitted photons: $\Delta E = hf$
	    • analyse the absorption of photons by atoms, with reference to:
	        • the change in energy levels of the atom due to electrons changing state
	        • the frequency and wavelength of emitted photons: hc E hf λ = =
	    • describe the quantised states of the atom with reference to electrons forming standing waves, and explain this as evidence for the dual nature of matter
	    • explain why classical laws of physics are not appropriate to model motion at very small scales.
	• Production of light from matter
	    • compare the production of light in lasers, synchrotrons, LEDs and incandescent lights.
	
	Assessment:
	• On completion of this unit the student should be able to provide evidence for the nature of light and matter, and analyse the data from experiments that supports this evidence.
	
	Key Skills:

	• Develop aims and questions, formulate hypotheses and make predictions
	    • determine aims, hypotheses, questions and predictions that can be tested
	    • identify independent, dependent and controlled variables
	• Plan and undertake investigations
	    • determine appropriate type of investigation: conduct experiments; design-build-testevaluate a device; explore operation of a device; solve a scientific or technological problem; perform simulations; access secondary data, including data sourced through the internet that would otherwise be difficult to source as raw or primary data through a laboratory or a classroom
	    • select and use equipment, materials and procedures appropriate to the investigation, taking into account potential sources of error and uncertainty
	• Comply with safety and ethical guidelines
	    • apply ethical principles when undertaking and reporting investigations
	    • apply relevant occupational health and safety guidelines while undertaking practical investigations
	• Conduct investigations to collect and record data
	    • work independently and collaboratively as appropriate and within identified research constraints
	    • systematically generate, collect, record and summarise both qualitative and quantitative data
	• Analyse and evaluate data, methods and scientific models
	    • process quantitative data using appropriate mathematical relationships, units and number of significant figures
	    • organise, present and interpret data using tables, line graphs, correlation, line of best fit, calculations of mean and fitting an appropriate curve to graphical data, including the use of error bars on graphs
	    • take a qualitative approach when identifying and analysing experimental data with reference to accuracy, precision, reliability, validity, uncertainty and errors (random and systematic)
	    • explain the merit of replicating procedures and the effects of sample sizes to obtain reliable data
	    • evaluate investigative procedures and possible sources of bias, and suggest improvements
	    • explain how models are used to organise and understand observed phenomena and concepts related to physics, identifying limitations of the models
	• Draw evidence-based conclusions
	    • determine to what extent evidence from an investigation supports the purpose of the investigation, and make recommendations, as appropriate, for modifying or extending the investigation
	    • draw conclusions consistent with evidence and relevant to the question under investigation
	    • identify, describe and explain the limitations of conclusions, including identification of further evidence required

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critically evaluate various types of information related to physics from journal articles, mass media and opinions presented in the public domain
discuss the implications of research findings and proposals

Communicate and explain scientific ideas

use appropriate physics terminology, representations and conventions, including standard abbreviations, graphing conventions and units of measurement
discuss relevant physics information, ideas, concepts, theories and models and the connections between them
identify and explain formal physics terminology about investigations and concepts
use clear, coherent and concise expression
acknowledge sources of information and use standard scientific referencing conventions

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<tr><td>VCAA - Physics Unit 4: How can two contradictory models explain both light and matter?</td><td>
Area of Study 3 (Outcome 3): Practical Investigation

Key knowledge:

independent, dependent and controlled variables
the physics concepts specific to the investigation and their significance, including definitions of key terms, and physics representations
the characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the selected investigation, including experiments (gravity, magnetism, electricity, Newton’s laws of motion, waves) and/or the construction and evaluation of a device; precision, accuracy, reliability and validity of data; and the identification of, and distinction between, uncertainty and error
identification and application of relevant health and safety guidelines
methods of organising, analysing and evaluating primary data to identify patterns and relationships including sources of uncertainty and error, and limitations of data and methodologies
models and theories, and their use in organising and understanding observed phenomena and physics concepts including their limitations
the nature of evidence that supports or refutes a hypothesis, model or theory
the key findings of the selected investigation and their relationship to concepts associated with waves, fields and/or motion
the conventions of scientific report writing and scientific poster presentation, including physics terminology and representations, symbols, equations and formulas, units of measurement, significant figures, standard abbreviations and acknowledgment of references.

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Assessment:

- On completion of this unit the student should be able to design and undertake a practical investigation related to waves or fields or motion, and present methodologies, findings and conclusions in a scientific poster

Key Skills:

- Develop aims and questions, formulate hypotheses and make predictions
    - determine aims, hypotheses, questions and predictions that can be tested
    - identify independent, dependent and controlled variables
- Plan and undertake investigations
    - determine appropriate type of investigation: conduct experiments; design-build-testevaluate a device; explore operation of a device; solve a scientific or technological problem; perform simulations; access secondary data, including data sourced through the internet that would otherwise be difficult to source as raw or primary data through a laboratory or a classroom
    - select and use equipment, materials and procedures appropriate to the investigation, taking into account potential sources of error and uncertainty
- Comply with safety and ethical guidelines
    - apply ethical principles when undertaking and reporting investigations
    - apply relevant occupational health and safety guidelines while undertaking practical investigations
- Conduct investigations to collect and record data
    - work independently and collaboratively as appropriate and within identified research constraints
    - systematically generate, collect, record and summarise both qualitative and quantitative data
- Analyse and evaluate data, methods and scientific models
    - process quantitative data using appropriate mathematical relationships, units and number of significant figures
    - organise, present and interpret data using tables, line graphs, correlation, line of best fit, calculations of mean and fitting an appropriate curve to graphical data, including the use of error bars on graphs
    - take a qualitative approach when identifying and analysing experimental data with reference to accuracy, precision, reliability, validity, uncertainty and errors (random and systematic)
    - explain the merit of replicating procedures and the effects of sample sizes to obtain reliable data
    - evaluate investigative procedures and possible sources of bias, and suggest improvements
    - explain how models are used to organise and understand observed phenomena and concepts related to physics, identifying limitations of the models

	• Draw evidence-based conclusions
	  ◦ determine to what extent evidence from an investigation supports the purpose of the investigation, and make recommendations, as appropriate, for modifying or extending the investigation
	  ◦ draw conclusions consistent with evidence and relevant to the question under investigation
	  ◦ identify, describe and explain the limitations of conclusions, including identification of further evidence required
	  ◦ critically evaluate various types of information related to physics from journal articles, mass media and opinions presented in the public domain
	  ◦ discuss the implications of research findings and proposals
	• Communicate and explain scientific ideas
	  ◦ use appropriate physics terminology, representations and conventions, including standard abbreviations, graphing conventions and units of measurement
	  ◦ discuss relevant physics information, ideas, concepts, theories and models and the connections between them
	  ◦ identify and explain formal physics terminology about investigations and concepts
	  ◦ use clear, coherent and concise expression
	  ◦ acknowledge sources of information and use standard scientific referencing conventions

References

- ACARA Senior School Curriculum Physics
  - https://www.australiancurriculum.edu.au/senior-secondary-curriculum/science/physics/
- VCAA VCE Curriculum Physics
  - https://www.vcaa.vic.edu.au/curriculum/vce/vce-study-designs/physics/Pages/Index.aspx