A Guide to Optical Phenomena

Teaching Approach

Lessons 01 – 04 are about the photoelectric effect, and should be used in the sequence given here since each lesson builds on the knowledge gained in the previous lesson. This topic is significant because it shows the particle nature of light. In Lesson 01 learners are introduced to the photoelectric effect, in Lessons 02 and 03 learners look at investigations of the factors that affect photoelectric emission, and in Lesson 04 learners are shown how to perform calculations regarding the photoelectric effect. Lessons 05 and 06 demonstrate the wave nature of light in emission and absorption spectra. They could be used either before or after the first four lessons, but Lesson 06 does build on, and so should be used after, Lesson 05. The Task Video can be used either formatively or summatively.

Video Summaries

Some videos have a 'PAUSE' moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day's lesson; if desired, learners can be given specific questions to answer in preparation for the next day's lesson

1. Photoelectric Emission

Learners are led to predict the properties of light most likely to cause photoelectric emission, if light is viewed as a wave. They are then shown that the empirical findings contradict this prediction and suggest that light should be viewed as a particle.

2. Factors Determining Photoelectric Emission 1

Learners are first familiarised with the features of the PHET photoelectric effect simulation, after which this simulation is used to investigate the effects of the frequency and intensity of incident light, and the type of metal, on photoelectric emission rate.

3. Factors Affecting the Rate of Photoelectric Emission

The PHET photoelectric effect simulation is used to investigate the effect of the intensity of incident light on the rate at which photoelectric emission occurs, and the effect of the frequency of incident light on the kinetic energy of electrons emitted during the photoelectric effect.

4. Calculations for Photoelectric Effect

Learners are led through four worked examples of calculations which relate to the photoelectric effect. Learners are shown how to use the equations $E=hf$, $W_0 = hf_0$, $KE_{max} = E - W_0$ and $\frac{1}{2} mv_{max}^2 = hf - hf_0$.

5. Emission spectra

Learners are shown how emission spectra are observed, their appearance and significance. They are also given an explanation of how they form.

6. Absorption Spectra

The formation and appearance of absorption spectra are explained and contrasted with emission spectra of the same element.

Resource Material

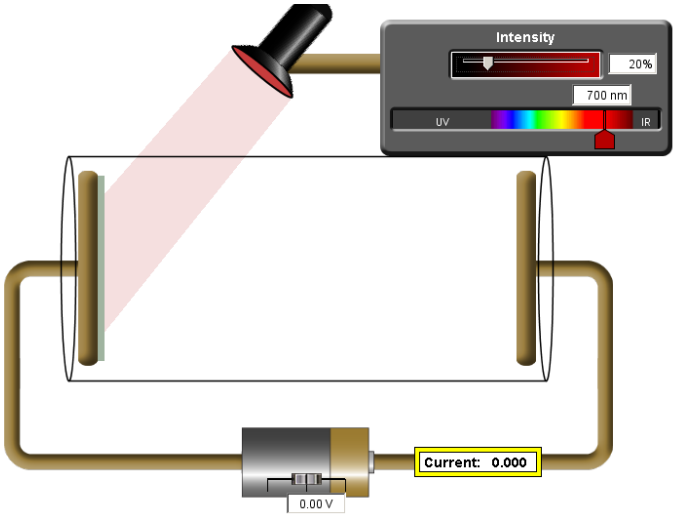
1. Photoelectric Emission	http://www.slideshare.net/AngelaStott/photoelectric-intro	Slideshare presentation containing many of the visuals used in this lesson.
	https://www.khanacademy.org/science/cosmology-and-astronomy/universe-scale-topic/light-fundamental-forces/v/introduction-to-light	Khan Academy movie: Introduction to light.
	http://science.howstuffworks.com/photoelectric-effect-support-particle-theory-light.htm	How stuff works: How does the photoelectric effect support the particle theory of light?
2. Factors Determining Photoelectric Emission1	http://phet.colorado.edu/en/simulation/photoelectric	PhET simulation: Photoelectric Effect.
	http://www.slideshare.net/AngelaStott/photoelectric-factors-affectingweb	Slideshare presentation containing many of the visuals used in this lesson.
	http://science.howstuffworks.com/light5.htm	How stuff works: How light works
3. Factors Affecting the Rate of Photoelectric Emission	http://www.slideshare.net/AngelaStott/photoelectric-factors-affectingweb	Slideshare presentation containing many of the visuals used in this lesson.
	http://everythingscience.co.za/grade-12/12-optical-phenomena-and-properties-of-matter/12-optical-phenomena-and-properties-of-matter-02.cnxmlplus	Everything Science Grade 12: The photoelectric effect
4. Calculations for Photoelectric Effect	http://www.slideshare.net/AngelaStott/photoelectric-calculations	Slideshare presentation containing many of the visuals used in this lesson.
	http://www.bbc.co.uk/bitesize/higher/physics/radiation/optoelectronics/revision/1/	Bitesize: Photoelectric emission
	http://everythingscience.co.za/grade-12/12-optical-phenomena-and-properties-of-matter/12-optical-phenomena-and-properties-of-matter-02.cnxmlplus	Everything Science Grade 12: The photoelectric effect.
	http://everythingscience.co.za/grade-12/12-optical-phenomena-and-properties-of-matter/12-optical-	Everything Science Grade 12: End of chapter exercises.

	phenomena-and-properties-of-matter-05.cnxmlplus	
5. Emission spectra	http://phet.colorado.edu/en/simulation/discharge-lamps	PhET simulation: Neon lights and other discharge lamp.
	http://phet.colorado.edu/en/simulation/hydrogen-atom	PhET simulation: Models of the Hydrogen Atom.
	http://www.slideshare.net/AngelaStott/spectra-33286110	Slideshare presentation containing many of the visuals used in this lesson.
6. Absorption Spectra	http://www.slideshare.net/AngelaStott/spectra-33286110	Slideshare presentation containing many of the visuals used in this lesson.
	http://www.bbc.co.uk/bitesize/higher/physics/radiation/optoelectronics/revision/2/	Bitesize: Spectra
	http://everythingscience.co.za/grade-12/12-optical-phenomena-and-properties-of-matter/12-optical-phenomena-and-properties-of-matter-03.cnxmlplus	Everything Science Grade 12: Emission and absorption spectra

Task

Question 1

A photoelectric cell is irradiated with low intensity red light of wavelength 700 nm. The photoelectric cell is connected to a circuit. No current reading is measured in the circuit.



1.1 Why is there no current in the circuit? Use the terms energy per photon, work function, threshold frequency, photoelectric emission.

1.2 For the red light of wavelength 700 nm calculate:

1.2.1 the light's frequency

1.2.2 the energy each photon of light carries.

(Speed of light, c = $3x10^8$ m•s^{-1}. Plank's constant, h = $6,63x10^{-34}$ J•s.)

1.3 What can you deduce about the value of this metal's work function?

1.4 Say whether each of the following statements is true or false:

If all other factors are kept constant then it is possible that current may be caused to flow in the circuit by:

1.4.1 an increase in the intensity of the red light

1.4.2 an increase in the frequency of the light

1.4.3 using a metal of lower work function.

1.5 A change is made so that current does flow in the circuit. Current strength is the rate of flow of charge (how much charge passes a point in the circuit each second). Explain why current strength increases with an increase in the light's:

1.5.1 Frequency

1.5.2 intensity.

You could use these terms: rate of photon emission, energy per photon, work function, kinetic energy, photoelectric emission, rate of flow of charge (current strength).

Question 2

Use this information to answer the questions which follow.

Metal	Threshold frequency (Hz)
Sodium	$6,67x10^{14}$
Caesium	$5,18x10^{14}$

Silver	$1,03x10^{15}$

2.1 Which of these three metals:
- 2.1.1 has the highest cut-off frequency
- 2.1.2 has the highest cut-off wavelength
- 2.1.3 has the highest work-function
- 2.1.4 holds its electrons tightest.

2.2 Calculate:
- 2.2.1 silver's work function
- 2.2.2 the maximum kinetic energy of the electrons emitted from silver by light of frequency $1,1x10^{15}$ Hz
- 2.2.3 the maximum speed of electrons emitted from silver by light of frequency $1,1x10^{15}$ Hz
  (Plank's constant, h = $6,63x10^{-34}$ J•s, mass of 1 electron = $9,11 \times 10^{-31}$ kg)

Question 3

A solar-powered calculator has a photoelectric cell. Whether the calculator turns on or not can be used as an indicator of whether photoelectric emission is occurring or not. You have a white light source of constant intensity, and a red, green and blue filter. You need to use this apparatus to investigate the question: How does light intensity affect whether or not photoelectric emission occurs or not?

3.1 What will you do with the apparatus, what is the independent variable and how will this be altered?
3.2 What variables will you need to control between the treatments?
3.3 What will you measure/record?
3.4 Describe the results which would support each of these hypotheses:
- 3.4.1 An increase in light intensity increases the likelihood that photoelectric emission will occur.
- 3.4.2 An increase in light intensity has no effect on the likelihood that photoelectric emission will occur.

3.5 Which of the hypotheses given in 3.4. Is correct: (a) / (b) / both (a) and (b) / neither (a) nor (b)?

Task Answers

Question 1

1.1 The frequency is lower than threshold. Therefore the energy per photon is less than the work function, i.e. less than the energy required to remove an electron from the surface of the metal. Therefore photoelectric emission will not occur.

1.2

1.2.1 $f = \frac{c}{\lambda}$

$f = \frac{3\times10^{8}}{700\times 10^{-9}}$

$f = 4{,}29 \text{ x } 10^{14} \text{ Hz}$

1.2.2 E = hf

$E = 6{,}63\text{x}10^{-34} \bullet 4{,}29\text{x}10^{14}$

$E = 2{,}84\text{x}10^{-19}$ J

1.3 This metal's work function is greater than 2,84x10-19 J.

1.4

1.4.1 F

1.4.2 T

1.4.3 T

1.5

1.5.1 This increases the energy per photon and therefore the amount of energy in excess of the work function that an emitted electron can have therefore increases average velocity at which electrons are emitted, increasing current strength.

1.5.2 This increases the rate at which photons strike the metal, transferring their electrons to the metal surface therefore increasing the number of electrons which can be emitted per time period therefore increasing the rate of flow of charge (current strength).

Question 2

2.1

2.1.1 Silver

2.1.2 Caesium

2.1.3 Silver

2.1.4 Silver

2.2

2.2.1 $W_0 = hf_0$

$W_0 = 6{,}63\text{x}10^{-34} \bullet 1{,}03\text{x}10^{15}$

$W_0 = 6{,}83\text{x}10^{-19}$ J

2.2.2 $KE_{max} = hf - W_0$

$KE_{max} = (6{,}63\text{x}10^{-34} \bullet 1{,}1\text{x}10^{15}) - 6{,}83\text{x}10^{-19}$

$KE_{max} = 4{,}64\text{x}10^{-20}$ J

2.2.3 $KE_{max} = \frac{1}{2} mv_{max}^{2}$

$v_{max} = \sqrt{\frac{2KE_{max}}{m}}$

$v_{max} = \sqrt{\frac{2(4{,}64\text{x}10^{-20})}{9{,}11\text{ x}10^{-31}}}$

$v_{max} = 3{,}19\text{x}10^{5}$ m•s^{-1}

Question 3

3.1 Place a solar powered calculator in a dark room. It should go off. Place the white light with a colour filter over it very far away from the calculator. This is the lowest light intensity treatment. Record whether it goes on or not. Gradually move the calculator closer to the light source. This

increases the intensity of the light incident to the calculator. The distance between the light and the calculator is an inverse indicator of the intensity of the light incident on the calculator, which is the independent variable. Repeat with the other filters.

3.2 Use the same calculator throughout the investigation. Use the same colour filter within one set of treatments of brightness changes.

3.3 You will record when the calculator goes on. This indicates that photoelectric emission is occurring

3.4

3.4.1 As you bring the calculator closer to any of the colours of light, the calculator should turn on.

3.4.2 As you bring the calculator closer to any of the colours of light, the calculator will either remain turned on or remain turned off.

3.5 (b)

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