SUBJECT and GRADE	Physical Sciences Gr 12
TERM 3	*Week 4*
TOPIC	Optical Phenomena and Properties of Materials (This section must be read in conjunction with the CAPS, p. 132–133.)
AIMS OF LESSONS	**Photo-electric effect** • Perform calculations using the photoelectric equation with graphs: $E = W_o + E_{Kmax}$, where $E = hf$ and $W_o = hf_o$ and $E_{Kmax} = \frac{1}{2}mv^2_{max}$ • Explain the effect of intensity and frequency on the photoelectric effect. **Emission and absorption spectra** • Explain the formation of atomic spectra by referring to energy transition. • Explain the difference between atomic absorption spectra and atomic emission spectra. An **atomic absorption spectrum** is formed when certain frequencies of electromagnetic radiation that passes through a medium, e.g. a cold gas, is absorbed. An **atomic emission spectrum** is formed when certain frequencies of electromagnetic radiation are emitted due to an atom's electrons making a transition from a high-energy state to a lower energy state.

<table>
<tr><td>RESOURCES</td><td>Paper based resources
You are referred to the:
Optical Phenomena topic and Emission and Absorption Spectra topic in the textbook or study guides that you will have on hand.
Examination Guideline (page 13)
Mind the Gap books (pages 142 - 147)
Past NSC Examination papers (refer to Paper 1)</td><td>Digital resources
Refer to the relevant digital resources:
https://wcedeportal.co.za
HeyScience App for Physical Sciences
Past NSC Examination papers
You Tube videos
Calculations on Photo electric effect
https://youtu.be/253wCijyZJo

Atomic Absorption Spectroscopy
https://youtu.be/YDh4EjyDmjc
An explanation of how Atomic Absorption Spectrum is formed
https://youtu.be/GO5KKAZoqeE

Bohr Model to explain Emission Spectra
https://youtu.be/sAPEAXQT9_Q

Emission and Absorption Spectra
https://youtu.be/1uPyq63aRvg</td></tr>
<tr><td>INTRODUCTION</td><td colspan="2">Part 1
You should be able to explain how a change in frequency or intensity affects the energy of an ejected photo-electron.
An increase in frequency, increases the energy of the photons only (increases the kinetic energy of the photoelectrons) and not the number of photoelectrons. The work function of the metal is constant and therefore the kinetic energy of the ejected electron increases.

An increase in intensity means that (for the same frequency) the number of photons per second increases but the energy of the photons stays the same. The work function of the metal is constant and therefore the kinetic energy of the ejected electron remains the same.
Observe the following youtube videos on calculations on Photo electric effect
https://youtu.be/253wCijyZJo</td></tr>
</table>

3. Now go through Mind the Gap (Activity 3, page 142)

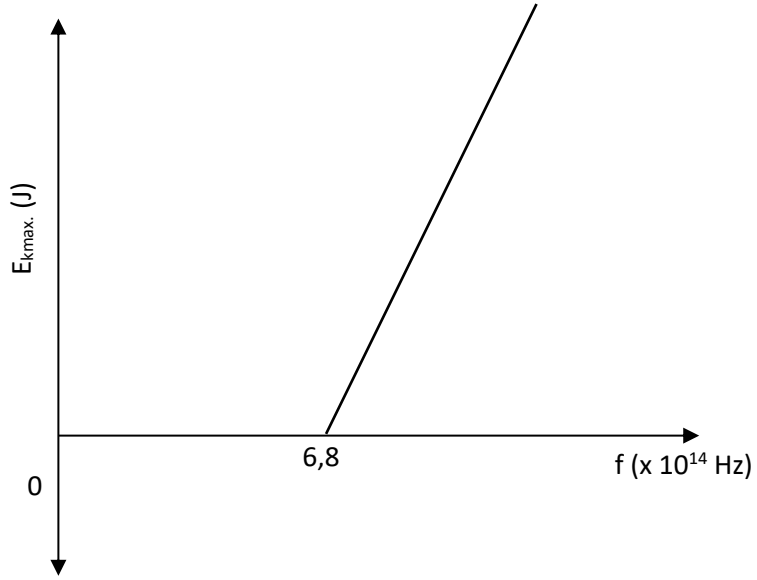
NB. Further explanation for Question 3: the threshold frequency (which is the minimum frequency) on the graph is the X-intercept.

Question 5: If light of higher intensity (of the same frequency) is used, the number of photons per second (of the same energy), incident on the metal, increases. The work function of the metal remains the same and therefore the kinetic energy of the ejected electron remains the same.

4. Now attempt the following question before you look through the memo.

QUESTION 1 DBE Gr 12 Feb -March 2017

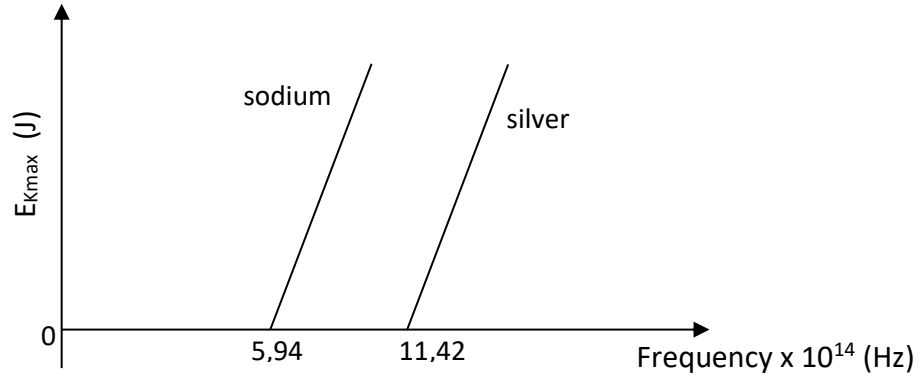
The graph below is obtained for an experiment on the photoelectric effect using different frequencies of light and a given metal plate



The threshold frequency for the metal is 6,8 x 10^{14} Hz.

1.1 Define the term *threshold frequency*. (2)

	In the experiment, the brightness of the light incident on the metal surface is increased. 1.2 State how this change will influence the speed of the photoelectrons emitted. Choose from INCREASES, DECREASES or REMAINS UNCHANGED. (1) 1.3 Show by means of a calculation whether the photoelectric effect will be OBSERVED or NOT OBSERVED, if monochromatic light with a wavelength of 6 x 10^{-7} m is used in this experiment. (5) 1.4 One of the radiations used in this experiment has a frequency of 7,8 x 10^{14} Hz.Calculate the maximum speed of an ejected photoelectron. (5) **[13]** ***Part 2*** You may now attempt question 2 and 3 from the CONSOLIDATION EXERCISES	
CONCEPTS AND SKILLS	***Part 3 and 4*** **Emission and absorption spectra (**You should be able to ….) • Explain the formation of atomic spectra by referring to energy transition. • Explain the difference between atomic absorption spectra and atomic emission spectra. An **atomic absorption spectrum** is formed when certain frequencies of electromagnetic radiation that passes through a medium, e.g. a cold gas, is absorbed. An **atomic emission spectrum** is formed when certain frequencies of electromagnetic radiation are emitted due to an atom's electrons making a transition from a high-energy state to a lower energy state. • Observe the following youtube video on: Atomic Absorption Spectroscopy https://youtu.be/YDh4EjyDmjc An explanation of how Atomic Absorption Spectrum is formed https://youtu.be/GO5KKAZoqeE	CAN YOU? • Define "photo-electric effect" • Do calculations on the photo-electric effect. • Do calculations on Photo-electric effect using graphs. • Explain how change in frequency and intensity affects the energy or number of ejected electrons from a metal surface. • Explain the difference between emission and absorption spectra

	Bohr Model to explain Emission Spectra https://youtu.be/sAPEAXQT9_Q Emission and Absorption Spectra https://youtu.be/1uPyq63aRvg	
ACTIVITIES/ASSESSMENT	***Part 5*** • Now work through the Activity 1 on Absorption and Emission Spectra from Mind the Gap pages 146 – 147 and/or any other textbook. • Now you can work through the questions under the Consolidation Heading Question 4	
CONSOLIDATION	**QUESTION 2 DBE Gr 12 Nov 2016** 2.1 A learner is investigating the photoelectric effect for two different metals, silver and sodium, using light of different frequencies. The maximum kinetic energy of the emitted photoelectrons is plotted against the frequency of the light for each of the metals, as shown in the graphs below.  2.1.1 Define the term *threshold frequency* (2) 2.1.2 Which metal, sodium or silver, has the larger work function? Explain the answer. (3) 2.1.3 Name the physical constant represented by the slopes of the graphs. (1) 2.1.4 If light of the same frequency is shone on each of the metals, in which metal will the ejected photoelectrons have a larger maximum kinetic energy? (1)	

2.2 In a different photoelectric experiment blue light obtained from a light bulb is shone onto a metal plate and electrons are released. The wavelength of the blue light is 470 x 10^{-9} m and the bulb is rated at 60 mW. The bulb is only 5% efficient.

2.2.1 Calculate the number of photons that will be incident on the metal plate per second, assuming all the light from the bulb is incident on the metal plate. (5)

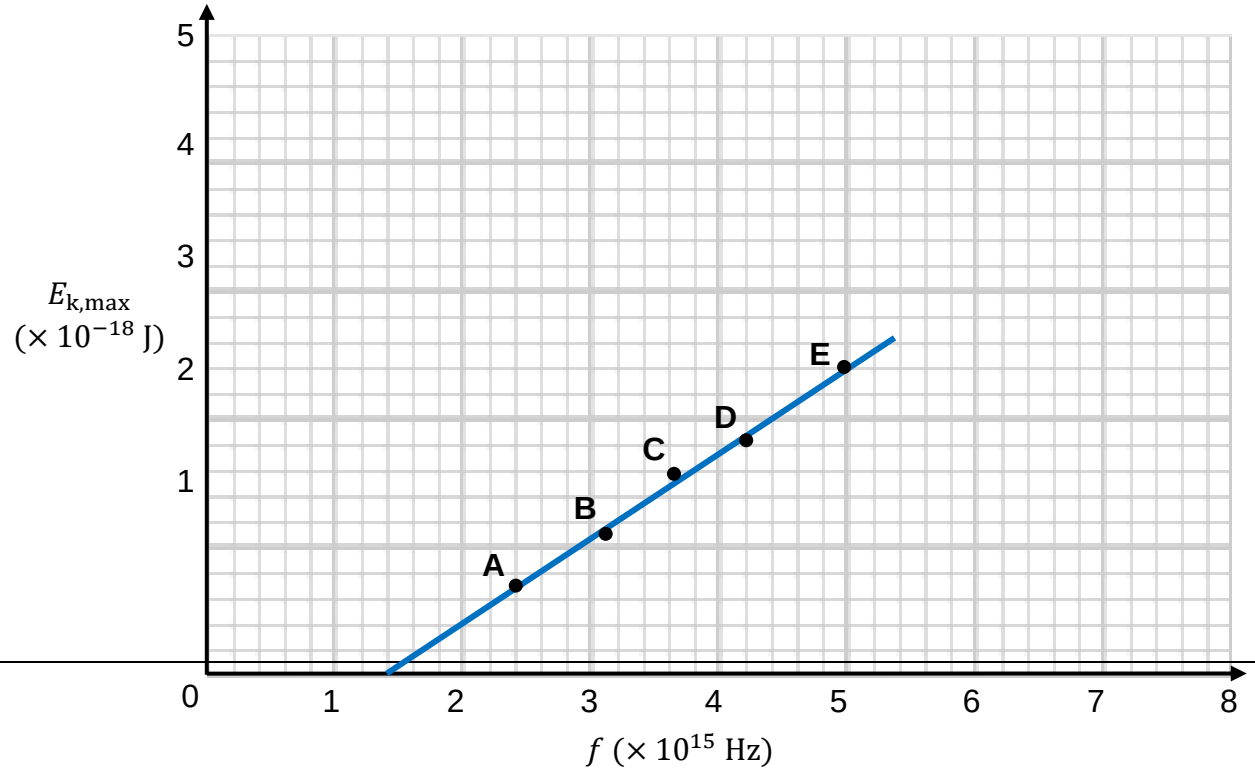
2.2.2 **Without any further calculation**, write down the number of electrons emitted per second from the metal. (1)

[13]

QUESTION 3

A group of physicists perform an experiment where they shine five different light sources (A, B, C, D and E) onto the platinum cathode of a photocell.

They measure the maximum kinetic energies of the ejected photoelectrons and produce the following graph of their results.



3.1 What does the gradient of the above graph represent? (1)
3.2 Define the term *threshold frequency*. (2)
3.3 Use the x-intercept of the graph in order to calculate the work function of the metal. (3)
3.4 In one of the experiments the brightness of one of the light sources was increased. How would this affect (Answer only INCREASES, DECREASES or REMAINS THE SAME for both of the following subquestions.)

3.4.1 the number of electrons ejected per second? (1)
3.4.2 the kinetic energy of the ejected electrons? (1)
3.5 Calculate the speed of an ejected electron when light source E is used. (4)
[12]

QUESTION 4
Download **DBE Gr 12 Nov 2017** question paper 1 and answer Q11

QUESTION 5
Download **DBE Gr 12 Nov 2016** question paper 1 and answer Q11

QUESTION 6 DBE Gr 12 May-June 2016
6.1 In an experiment on the photoelectric effect, light is incident on the surface of a metal and electrons are ejected.

6.1.1 What does the photoelectric effect indicate about the nature of light? (1)
6.1.2 The intensity of the light is increased. Will the maximum speed of the ejected electrons INCREASE, DECREASE or REMAIN THE SAME? Give a reason for the answer. (2)

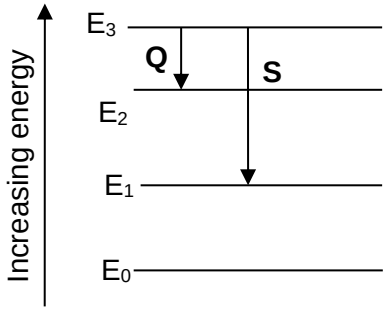
The wavelength corresponding with the threshold frequency is referred to as *threshold wavelength.*
The table below gives the values of threshold wavelengths for three different metals.

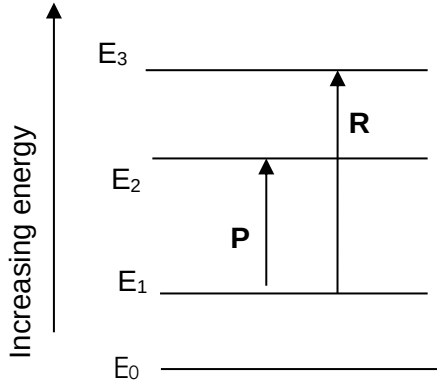
METAL	THRESHOLD WAVELENGTH (λ_0) IN METRES
Silver	$2{,}88 \times 10^{-7}$
Calcium	$4{,}32 \times 10^{-7}$
Sodium	$5{,}37 \times 10^{-7}$

In the experiment using one of the metals above, the maximum speed of the ejected electrons was recorded as $4{,}76 \times 10^{5}$ m·s^{-1} for light of wavelength 420 nm.

6.1.3 Identify the metal used in the experiment by means of suitable calculation. (5)

6.2 The simplified energy diagrams showing the possible electron transitions in an atom are shown below.





Using the letters **P**, **Q**, **R** and **S**, identify the lines that CORRECTLY show transitions that will result in the atom giving off an EMISSION SPECTRUM. Give a reason for the answer. (4)

[12]

Memo

1.1 The minimum frequency of light ✓needed to emit electrons from a certain metal surface.✓

Die minimum frekwensie van lig benodig om elektrone vanaf die oppervlak van 'n sekere metaal vry te stel. (2)

1.2 The speed remains unchanged. ✓ *Die spoed bly onveranderd.* (1)

1.3

OPTION 1/*OPSIE 1*

$c = f\lambda$✓,

$3 \times 10^8 = f\,(6 \times 10^{-7})$ ✓

$\therefore \quad f = 5 \times 10^{14}$ Hz✓

The value of f is less than the threshold frequency of the metal, ✓ therefore photoelectric effect is not observed.✓

Die waarde van f is laer as die drumpelfrekwensie van die metal, ✓en gevolglik sal foto- nie waargeneem word nie. ✓

OPTION 2/*OPSIE 2*

For the given metal/*Vir die gegewe metaal*

$W_0 = hf_0$✓

$= (6{,}63 \times 10^{-34})(6{,}8 \times 10^{14})$✓

$= 4{,}51 \times 10^{-19}$ J

For the given wavelength/*Vir die gegewe golflengte*

$$E_{photon/foton} = \frac{hc}{\lambda}$$

$$= \frac{(6{,}63\times10^{-34})(3\times10^{8})}{6\times10^{-7}}$$ ✓

$= 3{,}32 \times 10^{-19}$ J

$E_{photon/foton} = hf$

$=(6{,}63 \times 10^{-34})(5 \times 10^{14})$ ✓

This energy is less than the work function✓ of the metal,therefore photoelectric effect is not observed.✓

Hierdie energie is minder as die werksfunksie ✓*of die metal, en gevolglik sal foto-elektriese nie waargeneeme word nie.* ✓

(5)

1.4

$E = W_o + E_{k(max)}$

$E = W_o + \frac{1}{2}mv^2_{max}$

$hf = hf_o + \frac{1}{2}mv^2_{max}$

Any one of the three/*Enige van die drie* ✓

$\underline{(6,63 \times 10^{-34})(7,8 \times 10^{14})}$ ✓ = $\underline{(6,63 \times 10^{-34})(6,8 \times 10^{14})}$ + $\frac{1}{2}mv^2_{max}$✓

$\frac{1}{2} mv^2_{max} = 6,63 \times 10^{-20} J$

$\frac{1}{2} (9,11 \times 10^{-31}) v^2_{max/maks}$ ✓= $6,63 \times 10^{-20}$

$v_{max/maks} = 3,82 \times 10^5 \ m \cdot s^{-1}$✓ (5)

2.1.1The minimum frequency (of a photon/light) needed✓ to emit electrons from (the surface of) a metal. (substance) ✓

Die minimum frekwensie (van 'n foton/lig) benodig om elektrone vanaf die (oppervlakte van)'n metaal (stof) vry te stel *(2)*

2.1.2 Silver/*Silwer*✓

Threshold/cutoff frequency (of Ag) is higher/Drumpel/afsnyfrekwensie (van Ag) is hoër✓

W_o a f_o / $W_o = hf_o$ ✓

OR/OF

To eject electrons with the same kinetic energy from each metal, light of a higher frequency/energy is required for silver. ✓ Since $E = W_o + E_{k(max)}$ (and E_k is constant), the higher the frequency/energy of the photon/light required, the greater is the work function/W_o.✓

Om elektrone met dieselfde kinetiese energie van elke metal vry te stel,is lig van hoër frekwensie benodig vir silwer. Aangesien $E = W_o + E_{k(maks)}$ (en $E_{k(maks)}$ is konstant) word fotone/lig van hoër frekwensie/energie benodig, dus is arbeidsfunksie hoër. *(3)*

2.1.3 Planck's constant /*Planck se konstante* ✓ (1)

2.1.4 Sodium/*Natrium*✓ (1)

2.2.1 Energy radiated per second by the blue light */Energie per sekonde uitgestraal deur die bloulig*

$= \left(\frac{5}{100}\right)(60 \times 10^{-3})$ ✓ $= 3 \times 10^{-3}$ J·s^{-1}

2.2.1 $E_{photon/foton} = \frac{hc}{\lambda}$ ✓

$= \frac{(6{,}63 \times 10^{-34})(3 \times 10^{8})}{470 \times 10^{-9}}$ ✓ $= 4{,}232 \times 10^{-19}$ J

Total number of photons incident per second/*Totale aantal fotone wat per sekonde inval*

$= \frac{3 \times 10^{-3}}{4{,}232 \times 10^{-19}}$ ✓ $= 7{,}09 \times 10^{15}$ photons ✓ (5)

2.2.2 **POSITIVE MARKING FROM QUESTION 2.2.1 / *POSITIEWE NASIEN VANAF VRAAG 2.2.1***

$7{,}09 \times 10^{15}$ (electrons per second/*elektron per sekonde*) ✓

OR/*OF*

Same number as that calculated in Question 2.2.1 above/*Dieselfde as die in Vraag 2.2.1 hierbo bereken* *(1)*

[13]

QUESTION 3

3.1 Planck's constant ✓ (1)

3.2 *Threshold frequency* (f_0) is the minimum frequency of light ✓needed to emit **(**eject) electrons ✓ from the surface of a certain metal / material.

(2)

3.3

$W_0 = hf_0$✓

$= (6{,}63 \times 10^{-34})(1{,}4 \times 10^{15})$✓

$= 9{,}282 \times 10^{-19}$ J

(3)

	3.4.1 The greater brightness would: - <u>increase the number</u> ✓of photoelectrons 3.4.2 - but would have no <u>effect on their kinetic energies / Remain the same</u>✓ (2) 3.5 $E_{k,max,E} = \frac{1}{2} m_e v_{max,E}{}^2$ ✓ $2,4 \times 10^{-18}$ ✓ $= \frac{1}{2}(9,11 \times 10^{-31})$ ✓ $v_{max,E}{}^2$ $v_{max,E} = 2,3 \times 10^6 \text{ m} \cdot \text{s}^{-1}$ ✓ OR $E = W_o + E_k$ $E_k = E - W_o$ ✓ $\frac{1}{2} mv^2 = hf - W_o$ $\frac{1}{2}(9,11 \times 10^{-31}) v^2$ ✓ $= (6,63 \times 10^{-34})(5 \times 10^{15}) - (9,282 \times 10^{-19})$ ✓ $v = 2,29 \times 10^6 \text{ m} \cdot \text{s}^{-1}$ ✓ OR Learners can calculate the gradient of the graph which = $6,67 \times 10^{-34}$ and then use above method. (4) **[12]**
VALUES	• The use of Photo-electric effect in everyday usage, such as Solar Panels, Sound in Cinematography, Controlling of temperature in furnaces in Industry, switching street lights on and off etc. makes us more aware of how we should decrease our reliance on fossil fuels (especially carbon) for our livelihood. In this way we will reduce the production of greenhouse gases such as CO_2 • Atomic Absorption Spectroscopy can be applied in the Medical field and Biochemistry, Food Analysis, Environmental Analysis, metallurgy, Mineral Exploration, vaccine analysis etc.