2 Exercises and problems

Given in all exercises, unless indicated otherwise:
Planck's constant : $h = 6.6\times10^{-34}$ J.s ; Speed of light in vacuum : $c = 3\times10^{8}$ m/s ;
$1eV = 1.6\times10^{-19}$ J ; $e = 1.6\times10^{-19}$ C ; the mass of the electron $m_e = 9.1\times10^{-31}$ kg.

N° 1
Energy – power – intensity of the current

A beam of monochromatic light, of wavelength $\lambda = 0{,}44$ µm, is directed, with a power P = 10 mW, toward a photo-cell.

1) The light is formed of photons. Identify a photon.
2) Calculate the energy of a photon of light.
3) Find the number of photons captured by a cell during one minute.
4) Knowing that 5% of the photons are effective. Determine the intensity of the electric current in the cell.

N° 2
The Microwave

1) Calculate the energy of a Microwave photon of wavelength $\lambda = 1$ cm.
2) Find the number of photons necessary to raise the temperature of 0.25 kg of water from 20°C to 100° C.
Heat capacity of water : 4200 J/(kg.°C).

N° 3
Diverse

A – A monochromatic orange light, of wavelength $\lambda = 600$ nm, is projected on the metallic surface of Cesium of work function $W_S = 1{,}95$ eV.

1) Calculate the threshold wavelength of the metal.
2) Calculate the energy of a photon of orange light.
3) Deduce the maximum kinetic energy of an emitted electron from the metal and then its maximum speed.

B – a) Calculate the wavelength of a monochromatic radiation able to extract an electron from a tungsten, of work function $W_S = 4.52$ eV, with a maximum kinetic energy of 1.68 *eV*.
b) In what domain is this radiation found ?

C – A blue monochromatic light, of wavelength 482 nm, extracts from the surface of a sodium metal, an electron with a maximum kinetic energy 0.219 *eV*.
Calculate the work function and the threshold frequency of sodium.

N° 4
Solar power

The average solar power received by a country is 1 kW/m². Knowing that the average wavelength of the solar radiation is 550 nm. Calculate the number of photons received, per second, by an area of 1 cm².

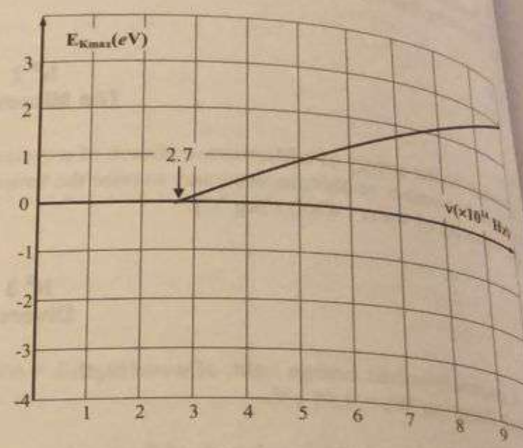
N° 5
Studying the photoelectric effect

The threshold wavelength of Potassium : $\lambda_0 = 0.55\,\mu m$.
A monochromatic light, of frequency $\nu = 6\times10^{14}$ Hz, illuminates a cell of potassium.

1) Calculate :
a) the work function of the metal.
b) the energy of a photon of the light.
c) the maximum speed with which an electron hits the cell.
2) To increase the speed of the electron should we change the frequency of the light or its power? Justify your answer.
3) To increase the intensity of the current in the cell should we increase the speed of the electron or the power of radiation?

N° 6
Graphical study

The graph, in the adjacent figure, represents the maximum kinetic energy of a photoelectron emitted by a metal as a function of the frequency of the incident radiation.



1) Calculate the maximum speed of an electron liberated by the metal under the impact of a radiation of wavelength 400 nm.
2) The graph cuts the axis of abscissa at a point A. Give the physical significance of the abscissa of this point.
3) The prolongation of the graph cuts the axis of ordinates at a point B. Give the physical significance of the ordinate of this point.
4) Calculate, in SI, the slope of the graph and give its unit. What does this slope represent ?
5) Represent in the same system the graph corresponding to the Barium metal whose work function is 2.5 eV.

N° 7
Photoelectric effect in a photocell

A lamp emits a monochromatic light, of wavelength λ = 570 nm, with a power P = 30 W, illuminates a cathode of cesium, of area s = 0.5 cm^2, placed at a distance R = 1 m from the lamp.
The work function of an electron of the cathode is W_0 = 1.89 eV.

1) Calculate the threshold wavelength of the cathode.
2) The light produced by the lamp can produce photoelectric effect. Justify.
3) Calculate then the maximum speed of the electron emitted by the cathode.
4) Calculate the luminous power received by the cathode.
5) Under the radiation λ, the electric current circulates in the cell and with intensity I = 3 μA.
a) Calculate the number of effective photons which attain the cathode during 1s. Deduce the effective power of the radiation.
b) Deduce the quantum efficiency of the cell.

N° 8

Using the graph to calculate the threshold wavelength and Planck's constant

A photoelectric cesium cathode cell, illuminates by a monochromatic radiation of wavelength λ in vacuum (of frequency ν), emits an electron with a kinetic energy E_K. We repeat this experiment with different radiations and we resume the results in the table below.

λ(nm)	600	550	500	450	400
E_K(eV)	0.163	0.35	0.575	0.85	1.2
ν ($\times 10^{14}$ Hz)					

1) The photoelectric effect gives evidence to a certain aspect of light. Name this aspect.
2) Complete the third line in the table.
Given : speed of light in vacuum $c = 3.10^8$ m/s.
3) Represent, on a graph paper, the graph of the kinetic energy E_K of the electron as a function of the frequency ν of the radiation. Scale : abscissa : 1 cm $\leftrightarrow$ 10^{14} Hz ; ordinate : 1 cm $\leftrightarrow$ 0.1 eV.
4) a) Write the expression giving E_K as a function of h, ν and the threshold frequency ν_0 of the metal.
b) Extract, using the graph, the threshold wavelength λ_0 of cesium and Planck's constant h.

N° 9

Photoelectric effect

We consider three photocells of cesium, magnesium and iron whose work functions are respectively 1.9 eV, 2.9 eV and 4.8 eV.
We illuminate each of the preceding cells by a visible monochromatic radiation of wavelength $\lambda = 0.55$ µm.

1) The cesium cell is only able to undergo photoelectric effect by a radiation $\lambda = 0.55$ µm. Justify.
2) A photocell of magnesium or of iron can't absorb, at the same instant, many photons and undergo photoelectric effect. Explain.
3) a) Calculate the maximum wavelengths λ_{0Cs} of the radiations capable of ejecting the electrons of the cells of Magnesium and iron.
b) In what domain is λ_{0Cs}.
c) What is the speed of the electron emitted from the cesium cell illuminated by radiation of wavelength λ_{0Cs} ?
4) The cesium cell is equipped by a micro ammeter, indicating a saturation current (all the electrons that leave the cathode attains the anode) of intensity $i_S = 40$ µA.
a) Calculate the number of electrons ejected by the metal during a second.
b) Knowing that the quantum efficiency of the cell is $\frac{1}{2000}$. Calculate the luminous power received by the cesium cathode.
c) How does the current i_S when we increase the power of the radiation $\lambda = 0.55$ µm ? Justify.

N° 10

Photoelectric cell under white light

The extraction energy of a photoelectric cell, of sodium cathode, is $W_S = 2.3$ eV. The cell is illuminated b lamp emitting white light, equipped by a color filter. When the lamp is equipped by a violet ($0.35\,\mu m \le \lambda_{violet} \le 0.42\,\mu m$) an electric current circulates in the cell but if it is equipped by a red light ($0.67\,\mu m \le \lambda_{red} \le 0.75\,\mu m$) no current circulates in the cell.

1) Specify whether the light emitted by the lamp, equipped by a violet filter, is monochromatic or polychromatic.
2) This experiment gives an evidence of the corpuscular aspect of light. Justify.
3) According to the corpuscular aspect, why does violet light realize the photoelectric effect ?
4) The kinetic energy E_K of an electron emitted by the cathode of the cell is included between two values. Determine these values.
5) a) Find E_K (in eV) as a function of the wavelength λ (in µm) of the violet radiation.
b) Trace the graph of E_K as a function of $\frac{1}{\lambda}$.
6) We feed the cell by an electric voltage which produces on the electron a retarding force whose work between the cathode and the anode, is (– 0.8 eV).
Extract graphically, the wavelengths, in the ultraviolet domain, of photons which can reassure the flow of electron to the anode.