الصفحة	الامتحان الوطني الموحد للبكالوريا	المملكة المغربية وزارة التربية الوطنية والتكوين المهني والتعليم العالي والبحث العلمي المركز الوطني للتقويم والامتحانات
1 7	المسالك الدولية الدورة العادية 2021 - الموضوع -	
*I	SSSSSSSSSSSSSSSSSS NS 28E	

3h	مدة الإنجاز	الفيزياء والكيمياء	المادة
7	المعامل	شعبة العلوم التجريبية مسلك العلوم الفيزيائية (خيار إنجليزية)	الشعبةأو المسلك

The use of non-programmable scientific calculator is allowed.

Literal expressions should be given before doing numerical calculations.

This exam paper consists of five exercises

Exercise I (7 points) :

- Kinetics study of a chemical reaction
- Study of an aqueous solution of a carboxylic acid

Exercise II (3 points) :

- Propagation of light waves

Exercise III (2,5 points) :

- Disintegration of plutonium-238

Exercise IV (4,75 points) :

- Response of RC dipole to a step voltage
- Electric oscillations in a LC circuit
- Amplitude modulation of a signal

Exercise V (2,75 points) :

- Study of a parachutist motion

Marking scale

EXERCISE I (7 points)

Part 1 and part 2 are independent

Part 1: Kinetics study of a chemical reaction

The manufacture of soap is one of the oldest syntheses. Soap is consisted of molecules which are obtained by reaction between an organic compound and an aqueous solution of sodium hydroxide. This part of the exercise aims, by conductiometric way, at studying the kinetics of the reaction between ethyl ethanoate of formula $CH_3COOC_2H_5$ and an aqueous solution of sodium hydroxide $Na^+_{(aq)} + HO^-_{(aq)}$.

At an instant taken as an origin of time t = 0, we introduce, in excess, an amount of the ethyl ethanoate in a balloon which contains an amount of substance $n_0(HO^-) = 10^{-3}$ mol of hydroxide ions. The volume of the reactionnal mixture is V_0 = 100mL.

The chemical reaction occurs at a constant temperature. The chemical equation of this reaction can be modelled as :

$$CH_3COOC_2H_{5(aq)} + HO^-_{(aq)} \rightarrow CH_3COO^-_{(aq)} + C_2H_5OH_{(aq)}$$

0,75 **1)** Draw the progress table of this reaction and find the value of the final progress x_f knowing that this reaction is total.

2) In periods of time, we measure the conductivity σ of the reactionnal mixture.

The curve in figure 1 represents the variations of the conductivity of the mixture as a function of time.

The line (T) is the tangent of the curve at a point of abscissa $t_1 = 4$ min.

The expression of the conductivity σ of the reactionnal mixture as a function of the progress x of the reaction is : $\sigma = 0,25 - 160.x$ where σ is expressed in $S.m^{-1}$ and x in mol.

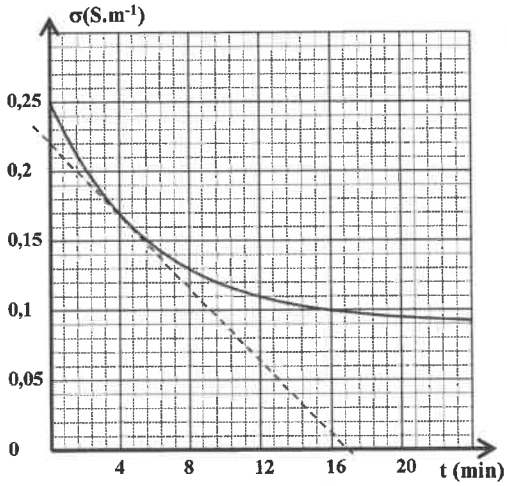


Figure 1

0,25 **2.1)** Define the half-life $t_{1/2}$ of a reaction.

0,5 **2.2)** Based on the expression $\sigma = f(x)$ and the curve in figure 1, determine the value of $t_{1/2}$.

0,5 **2.3)** Show that the volumetric rate of this reaction at an instant t is written as :

$$v = -\frac{1}{160.V_0}.\frac{d\sigma}{dt}.$$

0,5 **2.4)** Calculate, in $mol.m^{-3}.min^{-1}$, the value of v_1 the volumetric rate at t_1 = 4 min.

Part 2: Study of an aqueous solution of a carboxylic acid

An unlabelled bottle contains an aqueous solution S_a of a carboxylic acid of unknown formula and unknown concentration. This part of the exercise aims at :

- Determining the concentration of this solution.
- Identifying this acid.

We denote by AH the carboxylic acid and by A^- its conjugate base.

All measurements are made at 25°C.

1) Titration of the carboxylic acid

We titrate a volume V_a= 20 mL of an aqueous solution S_a of concentration C_a by using an aqueous solution S_b of sodium hydroxide $Na^+_{(aq)} + HO^-_{(aq)}$ of concentration $C_b = 10^{-1} mol.L^{-1}$.

The curve in figure 2 represents the variation of pH of the reactionnal mixture as a function of V_b the volume of the basic solution added.

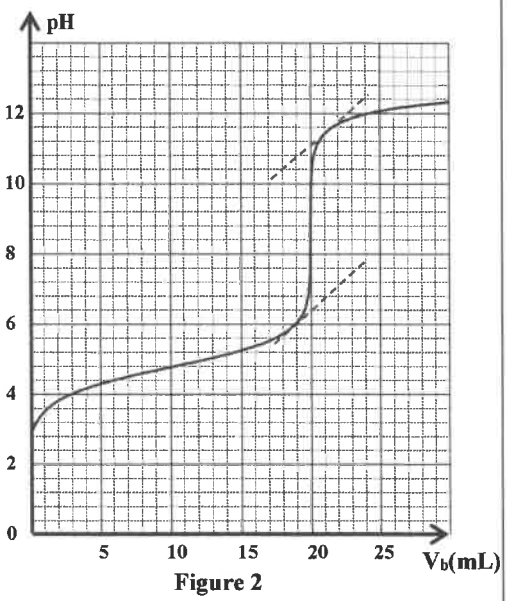


Figure 2

0,5 **1.1)** Write the equation of the titration reaction.

0,5 **1.2)** Determine graphically pH_E and V_{bE} coordinates of the equivalence point.

0,5 **1.3)** Determine the value of the concentration C_a.

2) Identification of the carboxylic acid

The solution S_a is prepared by dissolving the acid AH in water. The measurement of pH of the solution S_a is found to be: pH= 2,88.

0,5 **2.1)** Write the chemical equation of the reaction between the acid AH and water.

0,5 **2.2)** Show that the final progress rate τ of this reaction is $\tau \approx 1,32\%$.

0,75 **2.3)** Find out the expression of the reaction quotient of the reaction $Q_{r,eq}$ at equilibrium in terms of C_a and τ. Verify that $Q_{r,eq} \approx 1,77.10^{-5}$.

0,5 **2.4)** Based on the following table giving the values of pK_A of acid-base pairs, identify the carboxylic acid AH. Justify

Acid-base pairs	Value of pK_A
$HCOOH/HCOO^-$	3,75
$C_6H_5-COOH/C_6H_5-COO^-$	4,2
CH_3COOH/CH_3COO^-	4,75
$CH_3-CH_2-COOH/CH_3-CH_2-COO^-$	4,9

0,75 **3)** Determine the volume V_{b1} of the solution S_b should be added during the titration, for that $\frac{[AH_{(aq)}]}{[A^-_{(aq)}]} = 2,24$.

EXERCISE II (3 points)

Propagation of light waves

1) A cylindrical beam of white light is emitted by a source S, it strikes in normal direction one face of a prism (P) in glass and it passes out of the other face to form a visible spectrum on a screen (E). (figure 1)

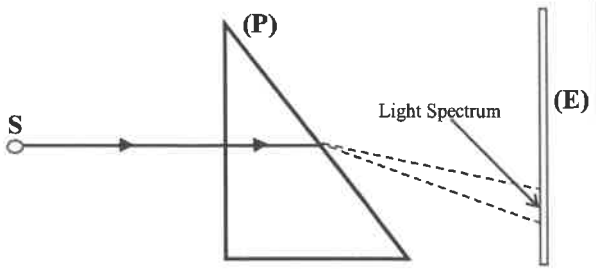


Figure 1

0,25 - Choose which one of the following statements, is true.

The previous experiment shows that the white light:

A	is monochromatic	**B**	includes just two different radiations	**C**	is polychromatic

2) We illuminate successively the prism (P) by two radiations: one is red and another is yellow.

Given :

- ✓ The speed of light in vacuum is $c = 3.10^8\ m.s^{-1}$.
- ✓ The wavelength of the red radiation in the prism is $\lambda_r = 474\ nm$.
- ✓ The frequency of the red radiation is $\upsilon_r = 3{,}91.10^{14}\ Hz$.
- ✓ The wavelengths of the yellow radiation are $\lambda_{0j} = 589\ nm$ in vacuum and $\lambda_j = 355\ nm$ in the prism (P).

0,5 **2.1)** Calculate the frequency υ_j of the yellow radiation.

0,5 **2.2)** Calculate the speeds v_j and v_r of the red and the yellow radiations in the prism.

0,25 **2.3)** Which property of the prism highlighted by results of the question 2.2)?

3) We illuminate a horizontal slit of width a = 0,06 mm by using a laser radiation of wavelength λ. A series of vertical spots are observed on a screen placed at a distance D of the slit. The length of the central spot is L (figure 2).

We vary the distance D and we measure the length L.

The curve in figure 3 gives the variation of L as a function of D: $L = f(D)$.

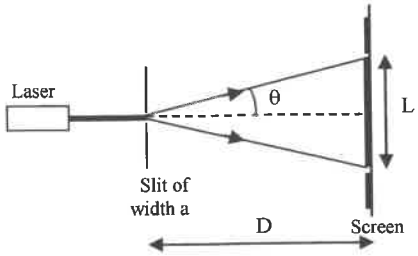


Figure 2

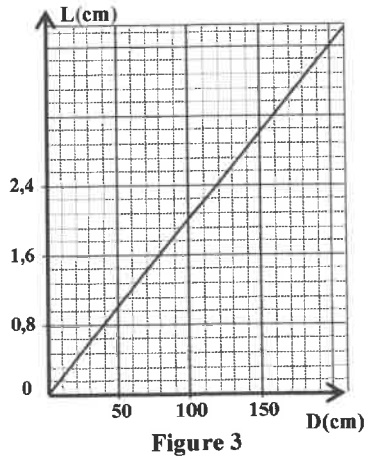


Figure 3

0,5 **3.1)** Find out the expression of L in terms of λ, a and D. (θ is small to take $\tan\theta \approx \theta$)

0,5 **3.2)** By using the curve $L = f(D)$, show that $\lambda = 600\ nm$.

0,5 **3.3)** We substitute the slit by a hair of diameter d. The distance between the slit and the screen is fixed to be $D_1 = 2\ m$.

With the same radiation of the wavelength λ, we obtain a central spot of length $L_1 = 3\ cm$.

Determine the diameter d of the hair.

EXERCISE III (2,5 points)

Disintegration of plutonium-238

The pacemaker is a device that can be placed inside the body to generate electrical impulses stimulating heart muscles. The purpose of the pacemaker is to help the heart to beat at a correct speed. The produced energy, by alpha disintegration of the plutonium-238,can be used to operate some pacemakers.

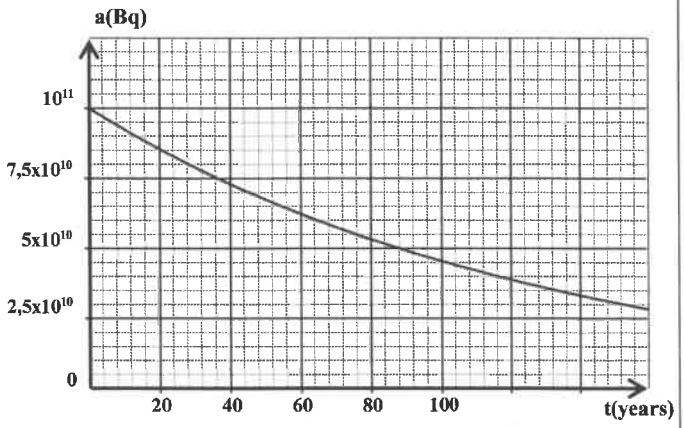
This exercise aims at studying a pacemaker operating by plutonium-238.

Given :

nucleus	Protactinium238	Uranium234	Uranium238	Neptunium238	Plutonium238
symbol	$^{238}_{91}Pa$	$^{234}_{92}U$	$^{238}_{92}U$	$^{238}_{93}Np$	$^{238}_{94}Pu$

0,5 **1)** Write the equation of the alpha disintegration of the plutonium-238 by identifying the produced nucleus.

2) The curve in figure at right represents the evolution of the activity a(t) of a plutonium-238 sample in the pacemaker. We take the instant of implanting this pacemaker into the patient body as an origin of time t=0.



0,5 **2.1)** Determine graphically the half-life $t_{1/2}$ of the plutonium 238.

0,5 **2.2)** Deduce that the value of the decay constant λ is $\lambda \approx 7,88.10^{-3}$ years^{-1}.

0,5 **2.3)** Calculate N_0 the number of nuclei of plutonium 238 at t=0 in this pacemaker. (we take : 1year = 365 days).

0,5 **3)** This pacemaker works in efficient way when the number of nuclei of plutonium-238 which decays is smaller than 30% of the number of nuclei of plutonium-238 presents in the sample at $t = 0$. Determine in years the maximal duration t_{max} of the efficient functioning of this pacemaker.

EXERCICE IV (4,75 points)

The circuits of some electric devices, used in our everyday life, are consisted of capacitors, inductors, resistors, integrated circuits…

The objective of this exercise is to study :

- the response of RC dipole to a step voltage;
- the electric oscillations in a LC circuit;
- the amplitude modulation of a signal.

I-Response of RC dipole to a step voltage

We perform the set-up sketched in figure 1, which is consisted of the following components:

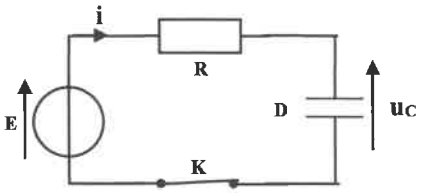


Figure 1

- an ideal generator of voltage of electromotive force E ;
- a capacitor D of capacitance C initially discharged ;
- a resistor of resistance $R = 10^3\ \Omega$;
- a switch K.

At an instant $t = 0$ taken as an origin of time, we switch on the circuit. A datalogger permits to plot the curve in figure 2 which represents the variations of $\frac{du_c}{dt}$ as a function of u_c which is the voltage between terminals of the capacitor at an instant t and $\frac{du_c}{dt}$ is the first derivative of u_c.

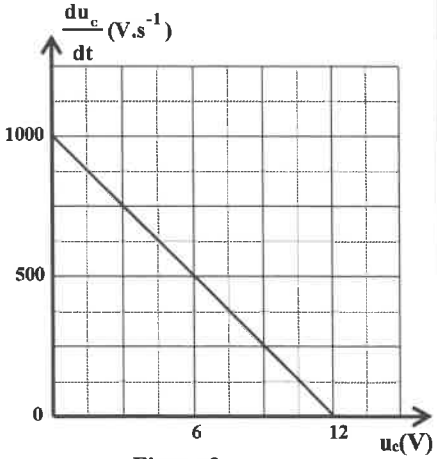


Figure 2

0,5 **1)** Show that the differential equation of the voltage $u_c(t)$ is written as : $\frac{du_c}{dt} = -\frac{1}{RC}u_c + \frac{E}{RC}$.

0,5 **2)** By exploiting the curve in figure 2, show that the capacitance of the capacitor is $C = 12\,\mu F$.

II- Electric oscillations in LC circuit

We perform the set-up sketched in figure 3, which is consisted of the previous capacitor D initially charged and an inductor of inductance L and of negligible resistance.

A datalogger permits to plot the curve of the evolution of the charge q(t) of the capacitor (figure 4).

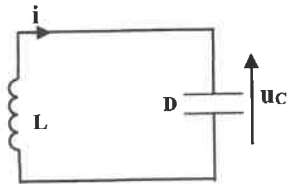


Figure 3

0,25 **1)** State from the three states of oscillations, which one highlighted by the curve in figure 4.

0,5 **2)** Find out the differential equation of the charge q(t) of the capacitor.

0,5 **3)** Find out the expression of the natural period T_0 of the oscillator in terms of L and C so that the expression $q(t) = Q_m \cos(\frac{2\pi}{T_0}t)$ is the solution of this differential equation.

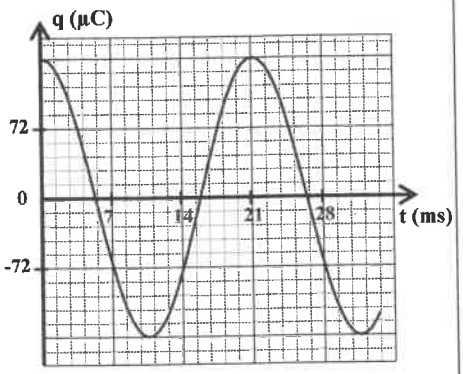


Figure 4

0,25 **4)** Determine graphically the value of T_0.

0,5 **5)** Deduce the value of L (we take $\pi^2 = 10$).

III- Amplitude modulation of a signal

To obtain an amplitude modulated signal, we perform the set-up sketched in figure 5, where the multiplier X is an integrated circuit which includes two inputs E_1 and E_2 and an output S.

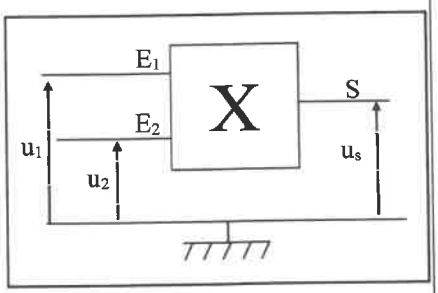


Figure 5

We apply :

- at the input E_1 a voltage $u_1(t)$ of expression $u_1(t) = C_m \cos(2\pi F_c.t)$.
- at the input E_2 a voltage $u_2(t)$ of expression $u_2(t) = U_0 + s(t)$

where $s(t) = S_m \cos(2\pi f_m.t)$ is the modulating voltage and U_0 is the DC component of this voltage.

At the output S of the multiplier X, we get an amplitude modulated voltage $u_s(t)$.

We visualise the voltage $u_1(t)$ at the input A and the voltage $u_2(t)$ at the input B of an oscilloscope (figure 6).

Given: Vertical sensitivity: **1 V / div**

Horizontal sensitivity: **2 ms/div**

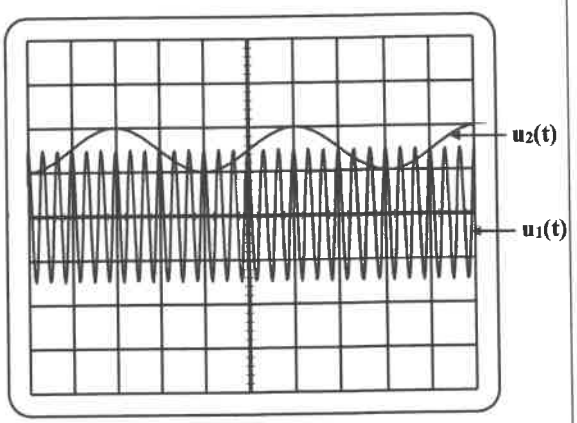


Figure 6

0,25 **1)** Define the amplitude modulation.

2) Determine graphically:

0,5 **2.1)** the frequencies F_c and f_m.

0,5 **2.2)** the value of S_m and that of U_0.

0,5 **3)** Do you get a good quality of modulation in this case? Justify your answer.

EXERCISE V (2,75 points)

The parachute is a device used to slow down the motion of a parachutist in vertical falling in the air.

This exercise aims at studying a simplified model of a parachutist motion.

The parachutist jumps out without initial velocity of a helicopter at rest at an altitude h from the ground.

We study the motion of the centre of inertia G of a system S, consists of a parachutist and its parachute, in a coordinate system $(O,\vec{k})$ considered as a Galilean frame of reference linked to the earth (figure 1). We consider that the trajectory of G is vertical and that the acceleration due to gravity (gravitational field strength) remains constant.

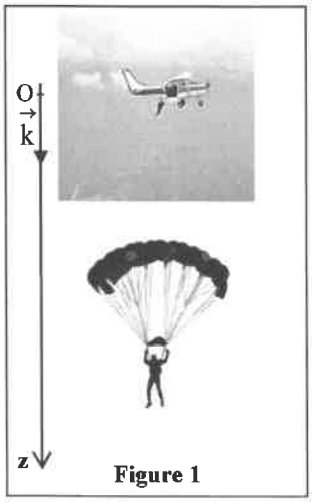


Figure 1

Given: - The mass of the system is m = 100kg ;

- The gravitational acceleration is $g = 10 m.s^{-2}$.
- The altitude h = 660m.

The motion of the system would be done in two phases:

1) Phase 1: the parachute is not deployed

The parachutist jumps out without initial velocity of a helicopter at an instant taken as origin of time t= 0. The fall in this phase is done and the parachute is not deployed.

We model the evolution of the speed of the centre of inertia G of the system during this phase by the curve in figure 2.

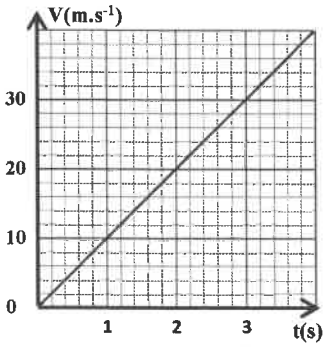


Figure 2

0,5 **1.1)** What is the nature of the motion of G? Justify your answer.

0,5 **1.2)** Would the motion be considered as a free fall in this phase? Justify your answer.

2) Phase 2: the parachute is deployed

After duration $\Delta t_1 = 4 s$ from the beginning of its fall, the parachutist deploys its parachute. We take the instant of deploying the parachute as a new origin of time of this phase 2.

During this phase, the system undergoing its weight and the air resistance which can be modelled as $\vec{F} = -\alpha.v^2.\vec{k}$ where v is the speed of G and α is a positive constant.

We model the evolution of the speed of G during this phase by the curve in figure 3.

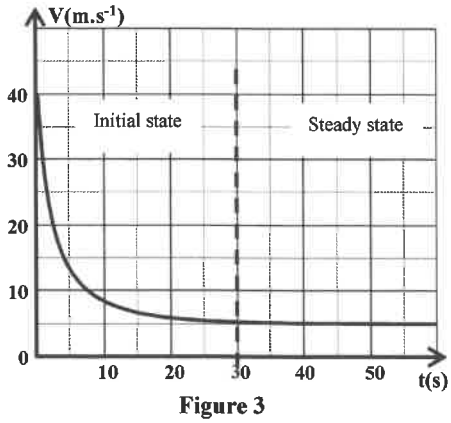


Figure 3

0,5 **2.1)** Show that the differential equation of the speed v is written as : $\frac{dv}{dt} + \frac{\alpha}{m}.v^2 = g$.

0,25 **2.2)** Find out the expression of the terminal speed v_ℓ of the motion in terms of m, g and α.

0,25 **2.3)** Determine graphically v_ℓ.

0,25 **2.4)** Deduce the value of α.

0,5 **3)** Knowing that the total duration of the motion of the system from jumping out to landing the ground is $\Delta t = 70 s$, determine the distance d travelled by G during the initial state of the phase 2.

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المسالك الدولية
الدورة العادية 2021
- عناصر الإجابة -

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المملكة المغربية
وزارة التربية الوطنية والتكوين المهني والتعليم العالي والبحث العلمي
المركز الوطني للتقويم والامتحانات

المادة	الفيزياء والكيمياء	مدة الإنجاز	3h
الشعبةأو المسلك	شعبة العلوم التجريبية مسلك العلوم الفيزيائية (خيار إنجليزية)	المعامل	7

EXERCISE I (7 points)

Question		Answers	Marking scale	Question reference in the framework
Part 1	1)	Progress table $x_f = 10^{-3}$ mol	0,5 0,25	- Exploit the different curves of time-evolution of the following: the amount of substance of a chemical specie, its concentration, the progress of a reaction, conductivity, conductance, pressure and volume. - Draw the progress table of a reaction and exploit it. - Know the expression of the volume rate of reaction. - Determine graphically the value of the volumetric rate of reaction. - Define the half-life $t_{1/2}$ of a chemical reaction. - Determine the half-life $t_{1/2}$ of the chemical reaction graphically or through exploiting the experimental results.
	2.1)	Definition of $t_{1/2}$	0,25	
	2.2)	Method $t_{1/2} = 4\,\text{min}$	0,25 0,25	
	2.3)	Method	0,5	
	2.4)	Method $v_1 \approx 0,8\,\text{mol.m}^{-3}.\text{min}^{-1}$	0,25 0,25	
Part 2	1.1)	$AH_{(aq)} + HO^-_{(aq)} \rightarrow A^-_{(aq)} + H_2O_{(l)}$	0,5	- Write the equation of titration reaction (use only one arrow) - Know the experimental set-up of an acid-base titration. - Exploit the curve or the results of the titration. - Determine and exploit the point of equivalence. - Write the equation of the acid-base reaction and identify the two pairs involved. - Calculate the final progress of the reaction that occurs between an acid and water taking into consideration the value of both the concentration and this acid's pH aqueous solution; then, compare it with the maximum progress. - Define the final progress rate of a reaction, and determine it using experimental data. - Give and use the expression of the reaction quotient Q_r through the reaction equation. - Know that, the reaction quotient in equilibrium $Q_{r,eq}$, associated to the reaction equation of a chemical system, takes a value independent of concentrations, called equilibrium constant K. - Write and use the expression of the acid dissociation constant K_A associated with the reaction of an acid with water. - Know the relationship $pK_A = -\log K_A$. - Determine the equilibrium constant associated to the equation of acid-base reaction using the acid dissociation constants of existing pairs. - Indicate the predominant chemical specie taking into consideration pH of aqueous solution and pK_A of pair acid/base.
	1.2)	$pH_E = 8,8$; $V_{bE} = 20\,\text{mL}$	2x0,25	
	1.3)	$C_a = \dfrac{C_b . V_{bE}}{V_a}$; $C_a = 10^{-1}\,\text{mol.L}^{-1}$	0,25 0,25	
	2.1)	$AH_{(aq)} + H_2O_{(l)} \rightleftarrows A^-_{(aq)} + H_3O^+_{(aq)}$	0,5	
	2.2)	Method	0,5	
	2.3)	$Q_{r,éq} = \dfrac{C_a . \tau^2}{1-\tau}$ check the value of $Q_{r,éq}$	0,5 0,25	
	2.4)	$pK_A = 4,75$ AH is CH_3COOH	0,25 0,25	
	3)	$pH = pK_A + \log\dfrac{[A^-]}{[AH]}$; $pH = 4,4$ $V_{bI} = 6\,\text{mL}$	0,5 0,25	

EXERCISE II (3 points)

Question	Answers	Marking scale	Question reference in the framework
1)	C	0,25	- Know (Recall) and exploit the relationship: $\lambda = \frac{c}{\upsilon}$. - Define a monochromatic and a polychromatic light. - Know the boundaries of wavelengths and their colours for the visible spectrum in the vacuum. - Know the frequency of a monochromatic radiation does not change as it passes from one transparent medium to another. - Know that the transparent media are more or less dispersive. - Know (Recall) and exploit the relationship: $n = \frac{c}{v}$ - Determine (find out) the refractive index of transparent medium for a given frequency. -Know (Recall) and exploit the relationship $\theta = \lambda/a$; and know the units and the meaning of θ and λ. - Exploit experimental measurements to verify the relationship $\theta = \lambda/a$.
2.1)	$\upsilon_j = \frac{c}{\lambda_j}$ $\upsilon_j = 5,09.10^{14}Hz$	0,25 0,25	
2.2)	$v_r = \lambda_r.\upsilon_r$; $v_r = 1,85.10^8 m.s^{-1}$ $v_j = \lambda_j.\upsilon_j$; $v_j = 1,81.10^8 m.s^{-1}$	0,25 0,25	
2.3)	The prism is a dispersive medium	0,25	
3.1)	Method $L = \frac{2\lambda D}{a}$	0,25 0,25	
3.2)	Method	0,5	
3.3)	$d = \frac{2\lambda D_1}{L_1}$ $d = 0,08\,mm$	0,25 0,25	

EXERCISE III (2,5 points)

Question	Answers	Marking scale	Question reference in the framework
1)	$^{238}_{94}Pu \rightarrow {}^{234}_{92}U + {}^{4}_{2}He$ $^{234}_{92}U$ is the produced nucleus	0,25 0,25	- Know the meaning (significance) of the symbol $^{A}_{Z}X$ and give the corresponding composition of the nucleus. - Know and exploit the two laws of conservation. - Define the radioactivity: α , β^+ & β^- and the $\gamma - radiation$. - Write the equation of a nuclear reaction by applying the two conservation laws. - Recognize the type of radioactivity using the equation of a nuclear reaction. - Know and exploit the law of the radioactive decay, and exploit its curve. - Exploit the relationships between τ , $t_{1/2}$ and λ (decay constant).
2.1)	$t_{1/2} \approx 88\,years$	0,5	
2.2)	$\lambda = \frac{\ln 2}{t_{1/2}}$	0,5	
2.3)	$N_0 = \frac{a_0}{\lambda}$ $N_0 \approx 4.10^{20}$	0,25 0,25	
3)	Method $t_{max} = 45,26\,years$	0,25 0,25	

EXERCISE IV (4,75 points)				
Question		**Answers**	**Marking scale**	**Question reference in the framework**
I-	1)	Method	0,5	-Represent the voltages (Electric Potential Difference) u_R and u_C using the receiver convention; and show the polarity of capacitor plates. - Know and exploit the relationship $i = \frac{dq}{dt}$ for a capacitor in receiver convention. - Know and exploit the relationship q = C.u. - Know the capacitance of a capacitor, its unit F and their submultiples $\mu F, nF$ and pF. - Determine the capacitance of a capacitor graphically or by calculation. - Find out the differential equation and verify its solution when the RC dipole is submitted to a step voltage.
	2)	Method	0,5	
II-	1)	Periodic state (Undamped state)	0,25	- Define and recognize the undamped (periodic), the underdamped (pseudo-periodic) and the overdamped (non-periodic) states. - Recognize and represent the variation curves of the voltage between capacitor terminals in terms of time for the three states mentioned above; and exploit them. - Find out the differential equation for the voltage between the capacitor terminals or for its charge $q(t)$ in the negligible damping case and verify its solution. - Know and exploit the expression of the charge $q(t)$ and deduce the current intensity expression $i(t)$ flowing in the circuit and exploit it. - Know and exploit the natural period expression.
	2)	Method $\frac{d^2q}{dt^2} + \frac{1}{LC}.q = 0$	0,25 0,25	
	3)	Method $T_0 = 2\pi\sqrt{LC}$	0,25 0,25	
	4)	$T_0 = 21\,ms$	0,25	
	5)	Method $L \approx 0,92\,H$	0,25 0,25	
III-	1)	Definition	0,25	- Know that the amplitude modulation process is to transform the modulated amplitude voltage to affine function of the modulating voltage. - know the required conditions to avoid over modulation. - Recognize the stages of the amplitude modulation. - Exploit the different experimental obtained curves. - Know the conditions allowing to get a good modulation.
	2.1)	$F_c = 1500\,Hz$; $f_m = 125\,Hz$	2x0,25	
	2.2)	$S_m = 0,5\,V$; $U_0 = 1,5\,V$	2x0,25	
	3)	$F_c >> f_m$ and m=0,33 (m<1) good modulation	0,25 0,25	

EXERCISE V (2,75 points)			
Question	**Answers**	**Marking scale**	**Question reference in the framework**
1.1)	uniformly accelerated (or varied) linear motion Justification	**0,25** **0,25**	- Define the vertical free fall. - Apply Newton's second law to find out the differential equation of a solid's centre of inertia motion in vertical free fall and solve it. - Know and exploit the characteristics of the uniformly accelerated straight line motion and its parametric equations (t is the parameter). - Exploit the velocity-time graph: $v_G=f(t)$. - Select the appropriate frame of reference to study motion. - Know and exploit the two models of frictional fluids (viscous forces): $\vec{F}=-kv\,\vec{i}$ and $\vec{F}=-kv^2\,\vec{i}$ - Exploit the curve $v_G=f(t)$ to determine: * the terminal speed; * the characteristic time τ; * the initial state and the steady state. - Apply Newton's second law to find out the differential equation of a solid's centre of inertia motion in frictional vertical fall.
1.2)	Free Fall Justification	**0,25** **0,25**	
2.1)	Method	**0,5**	
2.2)	$v_\ell=\sqrt{\frac{m.g}{\alpha}}$	**0,25**	
2.3)	$v_\ell=5\,m.s^{-1}$	**0,25**	
2.4)	$\alpha=40\,(USI)$	**0,25**	
3)	Method $d=400\ m$	**0,25** **0,25**	

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