| الصفحة | الامتحان الوطني الموحد للبكالوريا | المملكة المغربية<br>وزارة التربية الوطنية<br>والتكوين المهني<br>والتعليم العالي والبحث العلمي<br>المركز الوطني للتقويم والامتحانات |
|---|---|---|
| 1<br>7 | المسالك الدولية<br>الدورة العادية 2021<br>- 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.

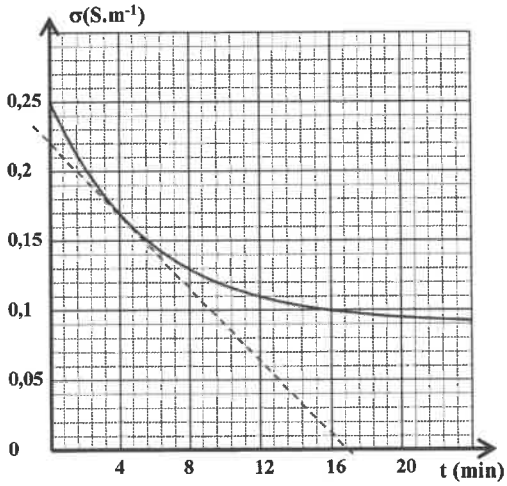


**Figure 1**

**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.

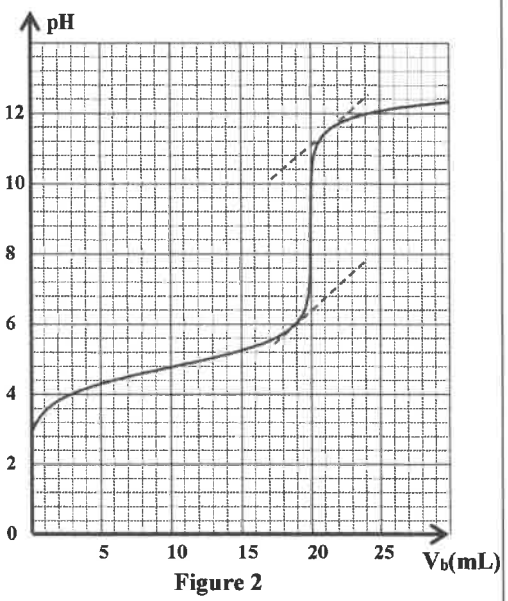


Figure 2

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 $\tau$ 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 $\tau$. 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)

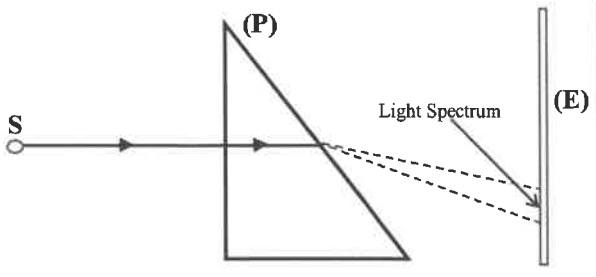


Figure 1

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 $\upsilon_j$ 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 $\lambda$. 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: $L = f(D)$.

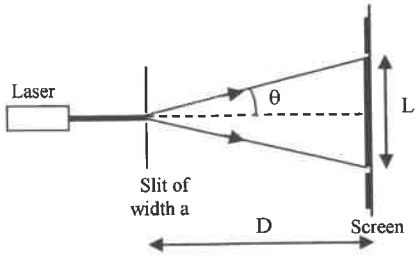



**Figure 2**

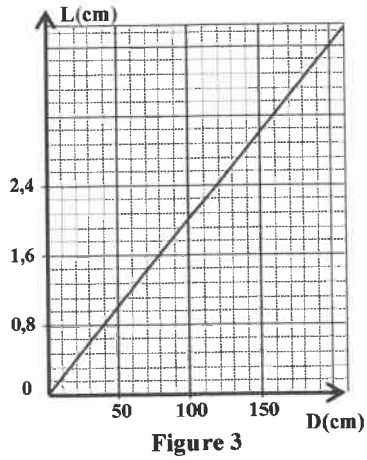



**Figure 3**

0,5 **3.1)** Find out the expression of L in terms of $\lambda$, a and D. ($\theta$ 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 $\lambda$, 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.

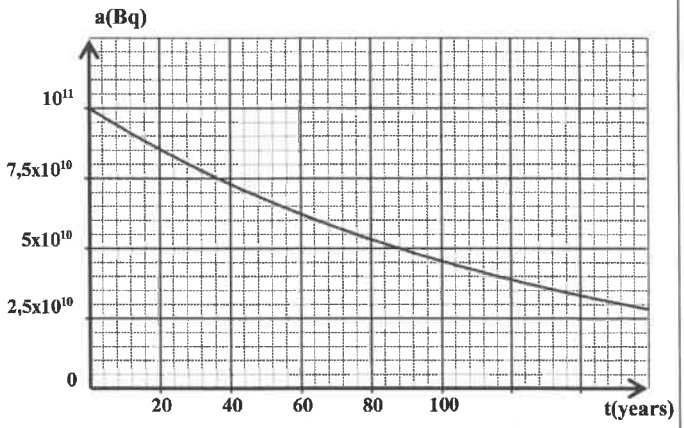
This exercise aims at studying a pacemaker operating by plutonium-238.

**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 $\lambda$ 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:

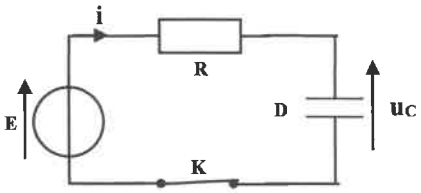


Figure 1

- 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 $u_c$.

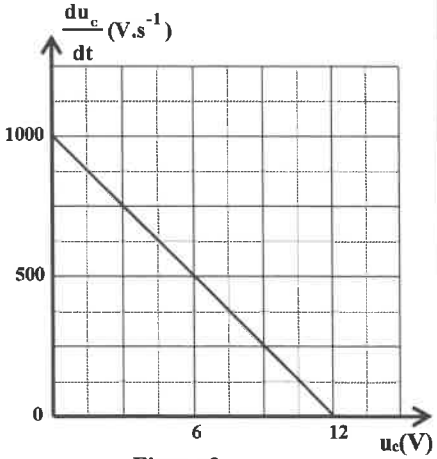


Figure 2

**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).

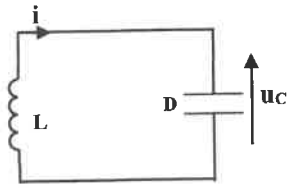


Figure 3

**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.

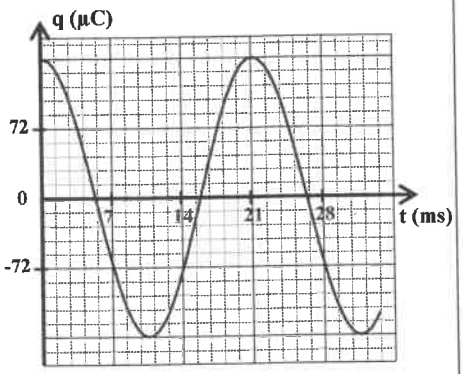


Figure 4

**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.

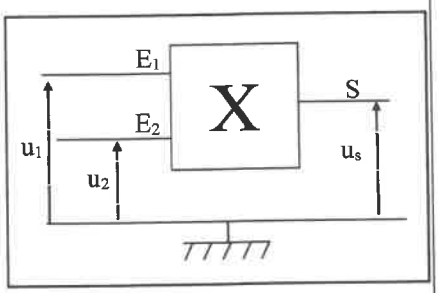


Figure 5

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**

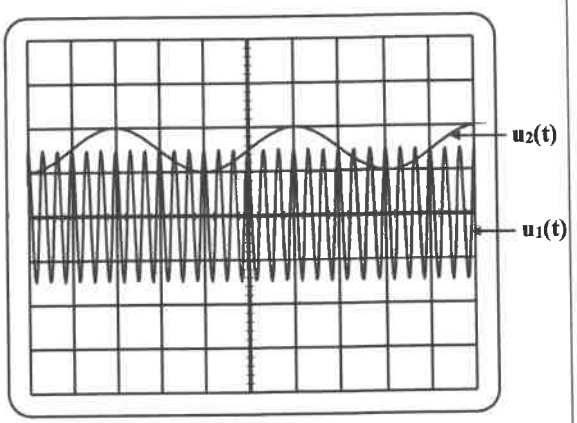


Figure 6

**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.

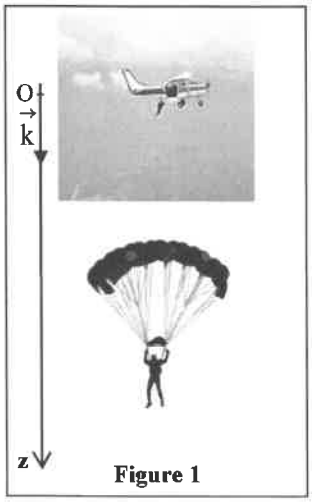


Figure 1

**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.

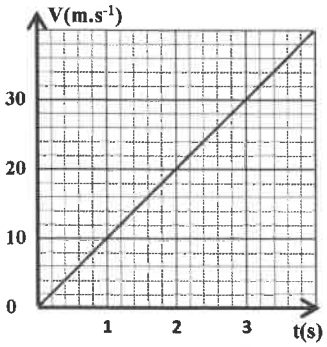


Figure 2

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 $\alpha$ is a positive constant.

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

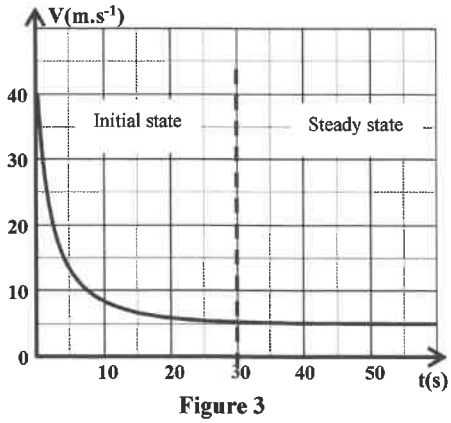


Figure 3

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 $v_\ell$ of the motion in terms of m, g and $\alpha$.

0,25 **2.3)** Determine graphically $v_\ell$.

0,25 **2.4)** Deduce the value of $\alpha$.

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.