الامتحان الوطني الموحد للبكالوريا
المسالك الدولية - خيار إنجليزية
الدورة العادية 2017
- الموضوع -

NS 28E

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

3	مدة الإنجاز	الفيزياء والكيمياء	المادة
7	المعامل	مسلك العلوم الفيزيائية – خيار إنجليزية	الشعبة أو المسلك

The use of non-programmable scientific calculator is allowed

This exam paper consists of four exercises

EXERCISE I (7 points):
- Electrochemical cell: aluminium-copper
- Butanoic acid reactions

EXERCISE II (2,5 points):
- Propagation of a mechanical wave on water surface

EXERCISE III (5 points):
- Response of RL dipole to a step voltage
- Amplitude modulation

EXERCISE IV (5,5 points):
- Study of the motion of a skier with frictional force
- Energetic study of the torsion pendulum

EXERCISE I (7 points)

Marking scale

Part one and part two are independent

Part one: Electrochemical cell; aluminium-copper

The functioning of the electrochemical cells is based on the principle of the conversion of a part of the chemical energy, produced by spontaneous chemical reactions, into a useful electric energy.

In this part, we suggest a simple study of the electrochemical cell : aluminium-copper.

To study an aluminum-copper electrochemical cell, we perform the following experiment:

-An electrode of copper metal is placed into a beaker which contains an aqueous solution of $Cu^{2+}_{(aq)} + SO^{2-}_{4(aq)}$ of volume $V = 65\,mL$. The initial molar concentration of $Cu^{2+}_{(aq)}$ is $\left[Cu^{2+}_{(aq)}\right]_i = 6,5.10^{-1} mol.L^{-1}$.

-An electrode of aluminum metal is placed into another beaker which contains the aqueous solution of $2Al^{3+}_{(aq)} + 3SO^{2-}_{4(aq)}$ of the same volume $V = 65\,mL$. The initial molar concentration of $Al^{3+}_{(aq)}$ is $\left[Al^{3+}_{(aq)}\right]_i = 6,5.10^{-1} mol.L^{-1}$.

-A salt bridge to connect solutions.

In series, an ammeter, a resistor and a switch are connected between the electrochemical cell poles. When we switch on the circuit, a steady electric current flows.

Given:

-The two redox pairs involved in the reaction are $Cu^{2+}_{(aq)} / Cu_{(s)}$ and $Al^{3+}_{(aq)} / Al_{(s)}$;

- Faraday constant : $1F = 9,65.10^4 C.mol^{-1}$;

-The equilibrium constant associated to the reaction $3Cu^{2+}_{(aq)} + 2Al_{(s)} \underset{(2)}{\overset{(1)}{\rightleftarrows}} 3Cu_{(s)} + 2Al^{3+}_{(aq)}$ is $K = 10^{200}$.

0,5 **1-** Write, at the initial state, the expression of the reaction quotient $Q_{r,i}$, and calculate its value.

0,5 **2-** Determine the spontaneous direction of the chemical system during the cell functioning (Justify your answer).

0,5 **3-** Give the cell diagram (cell notation) of the studied cell.

0,75 **4-** Find out the value of the amount of charge q flowing in the circuit when the value of the molar effective concentration of copper (II) ions is $\left[Cu^{2+}_{(aq)}\right] = 1,6.10^{-1}\,mol.L^{-1}$.

Part two: butanoic acid reactions

The butanoic acid C_3H_7COOH is used to synthesise perfumes, food flavours, etc.

This part of the exercise aims at studying the reaction between butanoic acid and water, and comparing the impact of this acid and its anhydride on the ethanol C_2H_5OH.

1- The reaction between butanoic acid and water:

In the chemistry lab, we prepare an aqueous solution of butanoic acid of volume V and of molar concentration $C = 1,0.10^{-2} mol.L^{-1}$. The pH value of this solution is $pH = 3,41$.

The occurring transformation is represented by the following chemical equation:

$$C_3H_7COOH_{(aq)} + H_2O_{(l)} \rightleftarrows C_3H_7COO^-_{(aq)} + H_3O^+_{(aq)}$$

0,75 **1.1-** Determine the final progress rate. What would you conclude?

0,75 **1.2-** Find out, at the equilibrium state, the expression of the reaction quotient $Q_{r,eq}$ of the chemical system in terms of C and pH, then calculate its value.

0,5 **1.3-** Deduce the value of pK_A of the pair $C_3H_7COOH_{(aq)} / C_3H_7COO^-_{(aq)}$.

2- The reactions of butanoic acid and butanoic anhydride with ethanol

To compare the impact of both butanoic acid and butanoic anhydride on the ethanol, we perform two separate experiments at the same temperature.

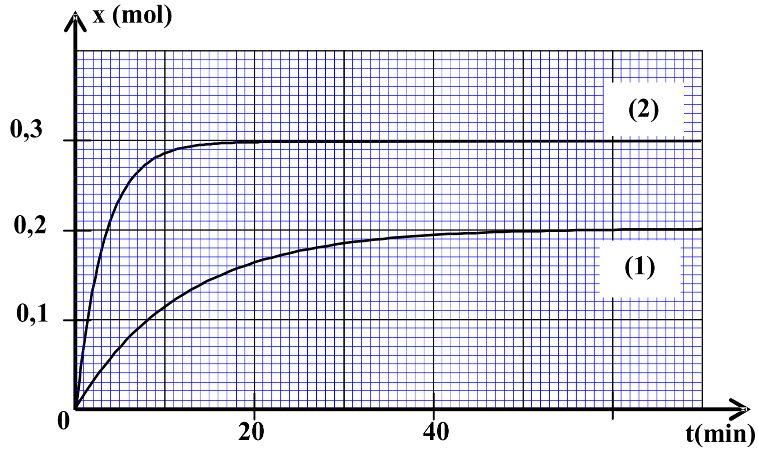
-The first experiment: In a flask, we prepare a mixture of the butanoic acid and the ethanol with the same amount of substance $n_0 = 0,3mol$ of each one, then we add some drops of concentrated sulphuric acid. Then we heat the reaction mixture under reflux. An esterification reaction occurs.

-The second experiment: In another flask, we prepare a mixture of the butanoic anhydride and the ethanol with the same amount of substance $n_0 = 0,3mol$ of each one, then we heat the reaction mixture under reflux. A chemical reaction occurs.

Curve 1 shows the evolution of the reaction progress x during the first experiment.

Curve 2 shows the evolution of the reaction progress x during the second experiment.

(See figure).



0,5 **2.1-** What is the purpose of heating by reflux?

0,75 **2.2-** Determine for each experiment the value of the half-life $t_{1/2}$ of the chemical reaction, and then deduce which reaction is faster.

0,75 **2.3-** Determine for each experiment the final progress rate, and then deduce which reaction is complete.

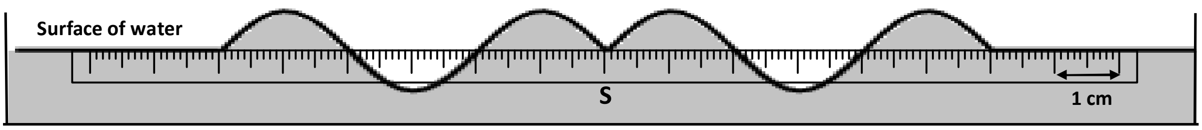
0,75 **2.4-** Using the structural formulae, write the equation of reaction occurring in the second experiment.

EXERCISE II (2,5 points)

Choose the right answer from list and copy it on your answer sheet next to the corresponding number of the question. (No justification or explanation is needed).

-Propagation of a mechanical wave on water surface

We produce, at the origin of time $t = 0$, in the point S on the water surface, a sinusoidal progressive mechanical wave of frequency $N = 50Hz$. The figure below represents the wave shape on the surface of water at one instant t of time. The ruler shows the scale used.



0,5 **1-** The wavelength is:

■ $\lambda = 0,2cm$ ■ $\lambda = 4cm$ ■ $\lambda = 5cm$ ■ $\lambda = 6cm$

0,5 **2-** The speed of the wave is :

■ v =2m.s^{-1} ■ v=200m.s^{-1} ■ v =3m.s^{-1} ■ $v = 8.10^{-4} m.s^{-1}$

0,75 **3-** the instant t, at which the aspect of the surface of the water is represented, is:

■ $t = 8s$ ■ $t = 0,03s$ ■ $t = 0,3s$ ■ $t = 3s$

0,75 **4-** We consider a point M, on the surface of water, far from S by SM = 6 cm. The point M repeats the same vibration as that of S with a time delay τ.

In this case, the relationship between the displacements of M and S is:

■ $y_M(t) = y_S(t-0,3)$ ■ $y_M(t) = y_S(t+0,03)$

■ $y_M(t) = y_S(t-0,03)$ ■ $y_M(t) = y_S(t+0,3)$

EXERCISE III (5 points)

In our everyday life we use a number of electric and electronic devices. The circuits of these devices contain resistors, inductors, capacitors and integrated circuits that perform different mathematical or logical operations.

The first part of this exercise aims at studying appearance and disappearance of the current in an inductor. The second part aims at studying the amplitude modulation.

Part one and part two are independent

Part one: Response of RL dipole to a step voltage

To study the RL dipole response to a step voltage, a teacher of physics performs with his students the electric circuit shown in figure1.

This circuit consists of:

-An ideal power supply of electromotive force E=6,5V;
- An inductor (coil) of inductance L and resistance r;
- A resistor of resistance $R = 60\,\Omega$;
- A double switch K.

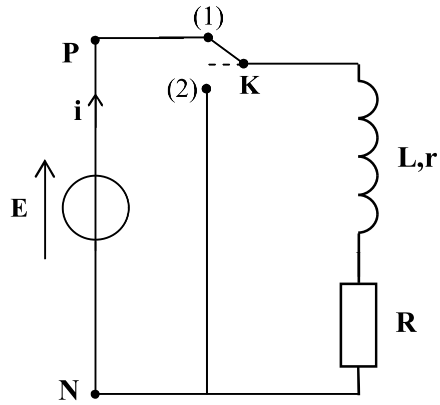


Figure 1

1- In the first step, the teacher studied the appearance of the electric current in the inductor by putting K at position (1).

0,25 **1.1-** Copy the circuit on your answer sheet and represent the voltage u_R between the resistor terminals using the receiver convention.

0,5 **1.2-** Find out, in the steady state, the expression of the electric current intensity I_p in terms of the circuit parameters.

2- In the second step, the teacher studied the disappearance of the electric current in the inductor. After obtaining the steady state and taking safety measures, the teacher puts at an instant $t = 0$, the switch K at position (2).

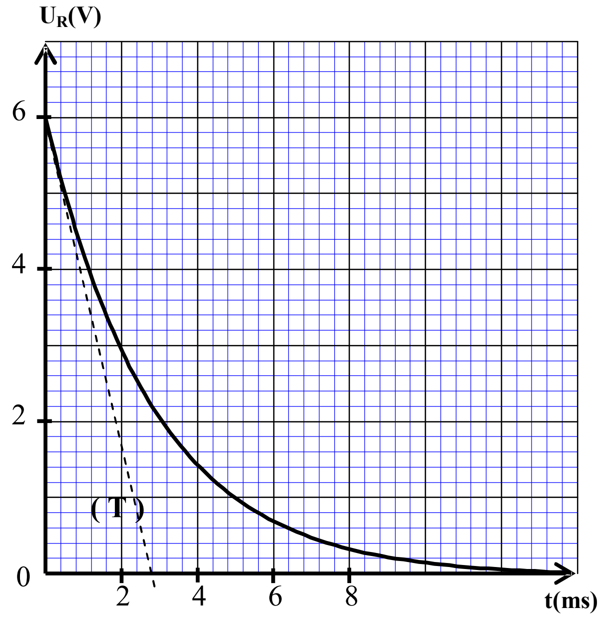


Figure 2

Using a datalogger, the teacher obtained the curve of voltage $u_R(t)$ variation between resistor terminals (figure2 page4).

The straight (T) represents the tangent of the curve at $t = 0$

0,5 **2.1-** Find out the differential equation for the voltage $u_R(t)$.

0,5 **2.2-** The solution of this differential equation is $u_R(t) = R.I_p.e^{-\frac{t}{\tau}}$. Find out the expression of the time-constant τ.

2.3- Exploiting the curve in figure 2:

0,5 **a-** Show that the resistance of the inductor is $r = 5\,\Omega$.

0,5 **b-** Verify that the approximate value of the inductance is $L = 182\ mH$.

0,5 **2.4-** Find out the value of the energy stored $\mathscr{E}_m$ in the inductor at the instant $t_1 = \tau$.

Part two: Amplitude modulation

To study the amplitude modulation and to check its quality during a practical work lesson, the teacher performs with his students the electric circuit shown in figure 3, using an integrated circuit (X) that makes the product. He applies a sinusoidal voltage $u_1(t) = P_m.\cos(2\pi.F_c.t)$ at E_1 and a voltage $u_2(t) = U_0 + s(t)$ at E_2, where U_0 is the direct current component (DC component) of the voltage $u_2(t)$ and $s(t) = S_m.\cos(2\pi.f_m.t)$ is the modulating voltage (figure 3).

The curve in figure 4 shows the output voltage $u_s(t) = k.u_1(t).u_2(t)$ which students observe on the oscilloscope screen. The positive constant k characterises the integrated circuit (X).

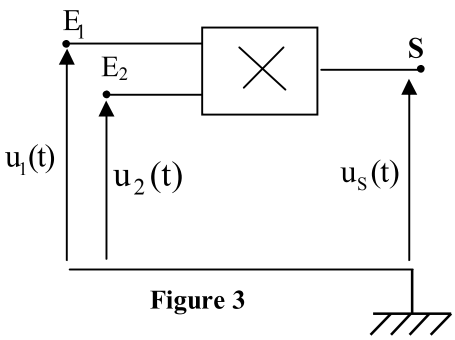


Figure 3

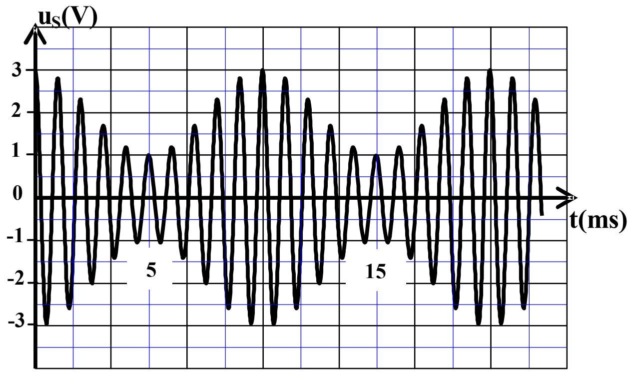


Figure 4

0,75 **1-** Show that the voltage $u_s(t)$ is written as: $u_s(t) = A\left[1 + m.\cos\left(2\pi f_m t\right)\right]\cos(2\pi F_c t)$, highlighting both expressions of A and m.

2- Exploiting the curve shown in figure 4:

0,5 **2.1-** Find out the values of F_c the frequency of the carrier voltage, and f_m the frequency of the modulating voltage.

0,5 **2.2-** Determine the value of the modulation index m. What would you conclude about the quality of the modulation?

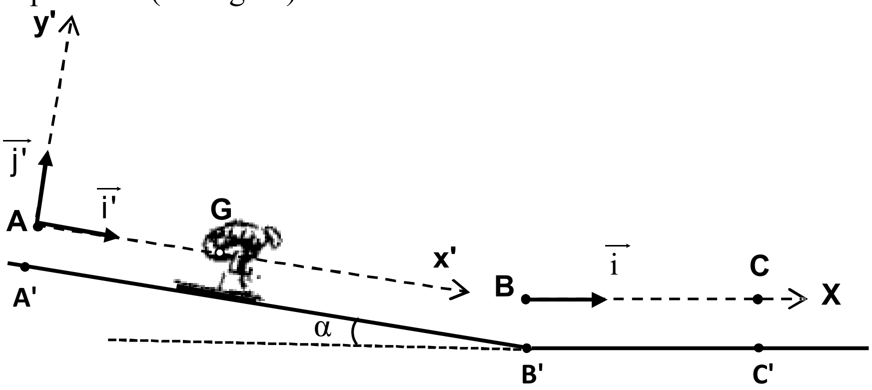
EXERCISE IV (5,5 points)

Part one and part two are independent

Part one: Study of the motion of a skier

In the winter, sliding down mountains is the best sport. It combines both adventure and fitness. This part aims at studying the motion of the centre of inertia of the skier and his accessories on a ski-jump ramp.

The skier slides on the ramp, which consists of two parts:
- The incline A'B' at angle α to the horizontal;
- The horizontal part B'C' (see figure).



Given:
- $g = 9,8\,m.s^{-2}$;
- Mass of the skier and his accessories: $m = 65\,kg$;
- The angle of the incline: $\alpha = 23°$;
- The air resistance is negligible.

1. Study of the motion on the incline

We study the motion of the centre of inertia G of a system (S) consisting of the skier and his accessories in the frame of reference $(A,\vec{i'},\vec{j'})$ linked to the earth. This frame is Galilean.
At the origin of time (t=0), the system (S) starts without initial velocity from position A (where A coincides with G).
The motion of G is on the plane AB according to the greater slope where AB = A'B'.
The system (S) slides down the incline with a steady frictional force; its magnitude is $f{=}15N$.

0,5 **1.1-** By applying the Newton second law, show that the differential equation of the velocity v_G of G is written as $\frac{dv_G}{dt} = g.\sin\alpha - \frac{f}{m}$.

0,5 **1.2-** The solution of this differential equation is $v_G(t) = \mathbf{b}.t + \mathbf{c}$. Determine the values of **b** and **c**.

0,5 **1.3-** Deduce the value of t_B , the instant when the centre G passes by position B with a velocity of $90\,km.h^{-1}$.

0,5 **1.4-** Find out the magnitude R of the force applied by the incline on the system (S).

2. Study of the motion on the horizontal plane

The system (S) keeps moving on the horizontal plane B'C' and it stops at position C'.
The system (S) moves on the horizontal plane with a steady frictional force; its magnitude is f'.
We study the motion of G on the horizontal frame $(B,\vec{i})$ linked to the earth frame which is Galilean.
The centre G passes by position B with a velocity of $90\,km.h^{-1}$ at an instant that we assume as a new origin of time (t=0).

0,5 **2.1-** By applying the Newton second law, find out the magnitude f' of the frictional force applied by the horizontal plane on the system (S), knowing that the x-component of acceleration of G is $a_x = -3\,m.s^{-2}$.

0,5 **2.2-** Determine t_C the instant when the system (S) stops moving.

0,5 **2.3-** Deduce the value of the distance BC travelled.

Part two: Energetic study of a torsion pendulum

Historically, the torsion pendulum was used by Cavendish to determine the universal gravitation constant. The torsion pendulum can be used to determine the torsion constant of some deformable solids.

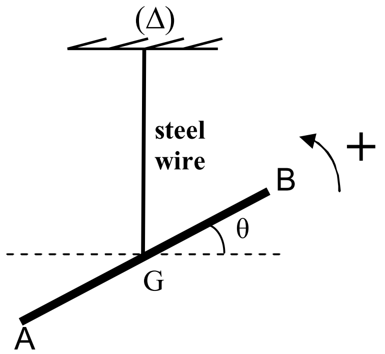
This part of exercise aims at determining both the torsion constant of a steel wire and the moment of inertia of a rod by exploiting the energy diagrams.

A torsion pendulum consists of a vertical steel wire of torsion constant C and a homogeneous rod AB of a moment of inertia J_Δ about a vertical axis (Δ). The axis (Δ) has the same direction as the steel wire. One end of the steel wire is attached to G the centre of inertia of the rod.

We turn the rod AB horizontally in the positive sense around the axis (Δ) at the angle $\theta_m = 0,8\,rad$ to the equilibrium position, then we release it without initial velocity at t=0 the origin of time.

We locate the position of the rod at one instant of time at the angular displacement θ to its equilibrium position (see figure).

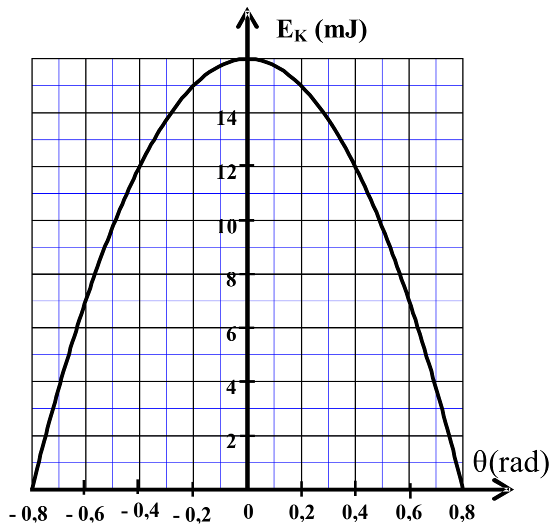
We study the motion of the pendulum in a frame of reference assumed Galilean.



We assume the torsional potential energy to be zero at the position of equilibrium and the gravitational potential energy to be zero on the horizontal plane passes by G.

All frictions are negligible.

The curve of the figure on the right represents the variation of the kinetic energy E_K of the pendulum with θ.



0,5 **1-** Write the expression of the mechanical energy E_m of the pendulum in terms of C, J_Δ, θ and $\dot{\theta}$ the angular velocity.

0,75 **2-** Determine the value of the torsion constant C of the steel wire.

0,75 **3-** Find out the value of J_Δ, knowing that the value of the maximum angular velocity of the pendulum is $\dot{\theta}_{max} = 2,31\,rad.s^{-1}$.

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EXERCISE I (7 points)

	Questions	Answers	Marking scale	Question reference In the framework
Part I	1	The expression : $Q_{ri} = \dfrac{\left[Al^{3+}_{(aq)}\right]_i^2}{\left[Cu^{2+}_{(aq)}\right]_i^3}$ $Q_{ri} \approx 1,54$	0,25 0,25	Calculate the value of the quotient of reaction Q_r of a chemical system in given state.
	2	-Comparaison between Q_{ri} and K -The forward direction (sense 1)	0,25 0,25	Determine the direction of spontaneous evolution of a chemical system.
	3	$\ominus Al_{(S)} / Al^{3+}_{(aq)} // Cu^{2+}_{(aq)} / Cu_{(S)} \oplus$	0,5	Draw a cell diagram / diagram of an electrochemical cell (battery)
	4	- The method used - The amount of charge is : $q \approx 6,15.10^3 C$	0,5 0,25	Establish the relationship between the amount of substance of chemical specie produced or consumed, the current intensity and the operating duration of a battery. Use this relationship to determine other quantities (quantity of charge, progress of the reaction, change of the mass...).
Part II	1.1	-The progress table -The final progress rate $\tau \approx 0,04$ or 4% -The reaction is non-complete	0,25 0,25 0,25	-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.
	1.2	$Q_{r,éq} = \dfrac{10^{-2pH}}{C - 10^{-pH}}$ $Q_{r,éq} \approx 1,57.10^{-5}$	0,5 0,25	Calculate the value of the quotient of reaction Q_r of a chemical system in given state.
	1.3	$pK_A \approx 4,8$	0,5	Know the relationship $pK_A = -\log K_A$
	2.1	Increasing the rate of reaction and avoiding the lost of the substance	0,5	Justify the choice of experimental equipment to be used: reflux apparatus, fractional distillation, crystallisation and vacuum filtration.

	2.2	-Experiment 1: $t_{1/2} \approx 8\,\text{min}$ -Experiment 2: $t_{1/2} \approx 2\,\text{min}$ -The reaction of the Experiment 2 is the fastest.	0,25 0,25 0,25	Determine the half-life t1/2 of the chemical reaction graphically or through exploiting the experimental results.
	2.3	-Experiment1: $0,67$ or 67% -Experiment 2: 1 or 100% -The reaction of the Experiment 2 is complete.	0,25 0,25 0,25	-Define the final progress rate of a reaction, and determine it using experimental data. -Know the characteristics of esterification and hydrolysis: non-complete and slow transformations. - Know the characteristics of the reaction of an anhydrous acid with an alcohol: fast and complete.
	2.4	-The structural formula of the butanoic anhydride. - the equation of the reaction .	0,25 0,5	Write the equation of the reaction of an anhydride acid with an alcohol

EXERCISE II (2,5 points)			
Questions	**Answers**	**Marking scale**	**Question reference in the framework**
1	$\lambda = 4cm$	0,5	- Exploit experimental documents and data in order to determine: * distance; * time delay; * wave speed. -Know (Recall) and use the relationship $\lambda = v.T$ - Know the relationship between displacement of a point from the propagation medium and the source displacement: $y_M(t) = y_S(t-\tau)$.
2	$v = 2\ m.s^{-1}$	0,5	
3	$t = 0,03\,s$	0,75	
4	$y_M(t) = y_S(t-0,03)$	0,75	

EXERCISE III (5 points)				
	Questions	**Answers**	**Marking scale**	**Question reference in the framework**
Part I	**1.1**	Representation of u_R	**0,25**	-Represent the voltages (Electric Potential Difference) u_R and u_L using the receiver convention. - Find out the differential equation and verify its solution when the RL dipole is submitted to a step voltage. - Determine the current's intensity expression $i(t)$ when the RL dipole is submitted to a step voltage, and deduce the voltage expressions between the inductor's terminals and the resistor terminals. -Know and exploit the time-constant expression. - Determine the two characteristics of the inductor (the inductance L, the resistance r) exploiting experimental results.
	1.2	$I_p = \frac{E}{R+r}$	**0,5**	
	2.1	the differential equation	**0,5**	
	2.2	$\tau = \frac{L}{R+r}$	**0,5**	
	2.3	a- Finding the value of r b-checking the value of L	**0,5** **0,5**	
	2.4	The method $\mathscr{E}_m \simeq 1,2.10^{-4}\ J$	**0,25** **0,25**	- Know and exploit the expression of the magnetic energy stored in a inductor.
Part II	**1**	*Finding the expression of $u_s(t)$ * $A = k.P_m.U_0$ * $m = \frac{S_m}{U_0}$	**0,25** **0,25** **0,25**	-Know that the amplitude modulation process is to transform the modulated amplitude voltage to affine function of the modulating voltage. -Recognise the stages of the amplitude modulation. -know the required conditions to avoid over modulation. -Exploit the different experimental obtained curves.
	2.1	$f_m = 100\,Hz$ $F_c = 1\,kHz$	**0,25** **0,25**	
	2.2	$m = 0,5$ Good amplitude modulation	**0,25** **0,25**	

EXERCISE IV (5,5 points)				
	Questions	**Answers**	**Marking scale**	**Question reference in the framework**
Part I	**1.1**	Finding the differential equation	**0,5**	-Know Newton's second law $\Sigma\overrightarrow{F_{ext}} = m.\frac{\Delta\overrightarrow{V_G}}{\Delta t}$ and $\Sigma\overrightarrow{F_{ext}} = m.\overrightarrow{a_G}$ and its range of validity. - Apply Newton's second law to find out the differential equation of a system's centre of inertia motion in horizontal or inclined plane and determine the characteristics of kinetic and dynamic quantities of motion. - Know and apply the Euler's method to solve approximately differential equation.
	1.2	$b \approx 3,6\,m.s^{-2}$ $c = 0$	**0,25** **0,25**	
	1.3	$t_B = \frac{v_G}{b}$ $t_B \approx 6,9s$	**0,25** **0,25**	
	1.4	$R = \sqrt{f^2 + (m.g.\cos\alpha)^2}$ $R \approx 586,6N$	**0,25** **0,25**	
	2.1	$f' = -m.a_x$ $f' = 195\,N$	**0,25** **0,25**	
	2.2	$t_c = -\frac{v_B}{a_x}$ $t_c = 8,33s$	**0,25** **0,25**	
	2,3	$BC = \frac{1}{2}a_x.t_c^2 + v_B.t_c$ $BC \approx 104,2\,m$	**0,25** **0,25**	
Part II	**1**	$E_m = \frac{1}{2}C.\theta^2 + \frac{1}{2}J_\Delta.\dot{\theta}^2$	**0,5**	- Know and exploit the expression of the mechanical energy of a torsion pendulum. - Exploit the energy diagrams.. -Know and exploit the expression of the torsional potential energy. - Exploit the conservation and the non-conservation of the mechanical energy of the torsion pendulum.
	2	$C = \frac{2.E_p}{\theta^2}$ $C = 5.10^{-2}\,N.m.rad^{-1}$	**0,5** **0,25**	
	3	$J_\Delta = \frac{2.E_{Kmax}}{\dot{\theta}_{max}^2}$ $J_\Delta = 6.10^{-3}\,kg.m^2$	**0,5** **0,25**	