الامتحان الوطني الموحد للبكالوريا
المسالك الدولية – خيار أنجليزية
الدورة العادية 2018
-الموضوع-

NS30E

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

4	مدة الإنجاز	الفيزياء والكيمياء	المادة
7	المعامل	شعبة العلوم الرياضية : " أ" و " ب" – خيار أنجليزية	الشعبة أو المسلك

The use of the non-programmable scientific calculator is allowed

This exam paper consists of four exercises; one in Chemistry and three in Physics.

Chemistry (7points)

- The chemical reactions of water with an acid and with an ester**,**
- The electrolysis of water.

Physics (13 points)

❖ Exercise 1: Nuclear Transformations (3,25 points)

- The $\alpha-$decay of the radium,
- The motion of the α-particle in a uniform magnetic field.

❖ Exercise 2 : Electricity (5 points)

- Response of the RC circuit to a step of voltage,
- Response of the RL circuit to a step of voltage,
- Forced oscillations in RLC series circuit.

❖ Exercise 3: Mechanics (4,75 points)

- The motion of an object in the air and in a liquid,
- The motion of an elastic pendulum.

Chemistry (7 points)

Water is chemical specie which plays an important role in chemistry of aqueous solutions. We will study in this exercise:

- An aqueous solution of an acid;
- Hydrolysis of an ester;
- Electrolysis of water.

1-Study of an aqueous solution of an acid HA:

We prepare an aqueous solution S_A of 2-methylpropanoic acid, denoted HA, of volume V and molar concentration $C = 10^{-2}\ mol.L^{-1}$. We denote by A^- the conjugate base of HA.

The measurement of pH of the solution S_A gives the value $pH = 3.44$.

0,25 **1-1-**Write the chemical equation of the reaction between the acid HA and water.

0,75 **1-2-** Calculate the final progress rate of the reaction, and deduce which chemical specie is predominant of the pair $HA_{(aq)}/A^-_{(aq)}$.

0,75 **1-3-** Find out the expression of the constant pK_A of the pair $HA_{(aq)}/A^-_{(aq)}$ in terms of C and pH. Check that $pK_A \approx 4.86$.

1-4-We take a volume $V_A = 20\,mL$ of the aqueous solution S_A to which we add progressively a volume V_B of an aqueous solution (S_B) of sodium hydroxide $Na^+_{(aq)} + HO^-_{(aq)}$ of molar concentration $C_B = C$ where $V_B < 20\,mL$.

0,5 **1-4-1-** Write the chemical equation of the occurring reaction (the reaction is considered complete).

0,5 **1-4-2-** Find out the value of the volume V_B of the aqueous solution (S_B) added at the moment when pH of the reaction mixture is $pH = 5.50$.

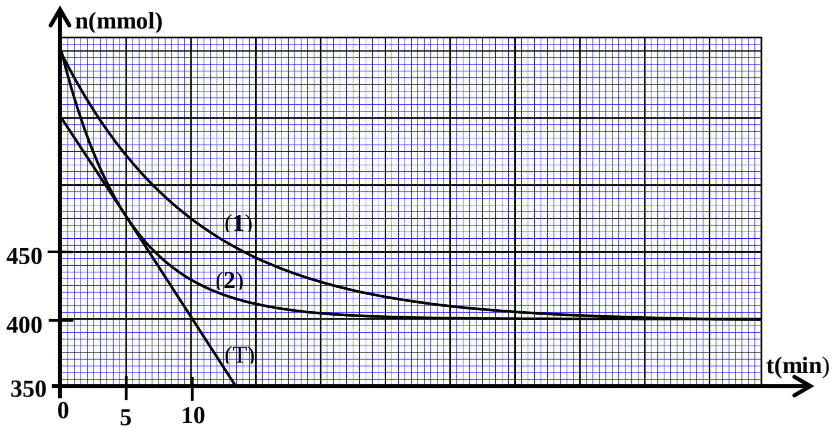
2- Hydrolysis of an ester:

The ester ethyl 2-methylpropanoate, whose structural formula is $CH_3-CH(CH_3)-C(=O)-O-CH_2-CH_3$, is characterized by strawberry flavour.

The hydrolysis of this ester, denoted E, produces an acid and an alcohol.

We perform two equimolar mixtures of the ester E and water. The volume of each mixture is V_0.

The curves (1) and (2), shown in figure on the right, represent the evolution of the amount of the ester E during the time at constant temperature θ.



One of the two curves is obtained when the catalyst is not used during the hydrolysis reaction.

0,5 **2-1-** Using a structural formulae, write the equation of the occurring reaction.

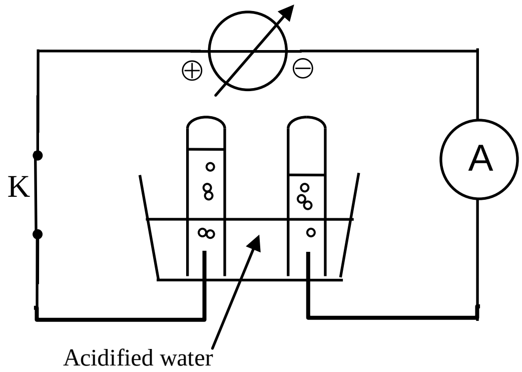
0,75 **2-2-** Determine graphically the half-life of the chemical reaction corresponding to curve (1).

0,5 **2-3-** Indicate, justifying your answer, the curve which corresponds to the hydrolysis reaction performed without the use of the catalyst.

0,75 **2-4-** Using the curve (2), determine the volumetric rate of the reaction expressed in $mol.L^{-1}.min^{-1}$, at the instant of time $t_1 = 5\,min$ ((T) represents the tangent of the curve (2) at the instant t_1). We take the volume of the mixture $V_0 = 71\ mL$.

1- Electrolysis of water:

We introduce a volume of acidified water in an electrolysis cell. We put on the top of each graphite electrode a test tube, filled in water, used to recover the generated gases, and then we set up the mounting shown in figure below.



After the switch is closed, at an instant of time assumed as origin of time (t=0), we adjust the electric current to the value I=0,2A.

Given:

-The Ox/Red pairs involved in the electrolysis reaction are: $O_{2(g)}/H_2O_{(\ell)}$ and $H^+_{(aq)}/H_{2(g)}$;

-The molar volume at the experimental conditions is : $V_m = 24\,L.mol^{-1}$;

- $N_A = 6{,}02.10^{23}\,mol^{-1}$; $e = 1{,}6.10^{-19}\,C$.

0,5 **3-1-** How many statements are true, from the following?

a- The electrode linked to the positive terminal of the power supply is the anode;
b- The forced transformation is a reaction which occurs in the opposite direction of a spontaneous transformation.
c- During the functioning of the electrolysis cell, the reduction reaction is produced at the anode;
d- The electric current emerges from the cathode of an electrolysis cell.

0,5 **3-2-** Write the chemical equation at the anode.

0,75 **3-3-** Find out the expression of the volume of the dioxygen gas generated at an instant t, in terms of I, V_m, N_A, e and t. Calculate its value at the instant $t = 8\,min$.

Physics (13 points)

Exercise 1: Nuclear transformations (3,25 points)

We aim in this exercise at studying the $\alpha-$decay of radium and the motion of α-particle in a uniform magnetic field.

1- In 1898, Marie and Pierre Curie announced the discovery of the two radioactive elements: the polonium and the radium. The radium $^{226}_{88}Ra$ which decays to radon $^{222}_{86}Rn$, is considered as an historical example of the $\alpha-$decay. The radium was chosen as a reference for calculating the activity of radioactive samples. The activity was expressed in Curie (1Ci) for years, before using the becquerel as a unit.

The Curie (1Ci) is the activity of a sample of one gram (1g) of radium 226.

Given: - Molar mass of radium: $M = 226\,g.mol^{-1}$; Avogadro constant : $N_A = 6{,}02.10^{23}\,mol^{-1}$;

- The binding energy of the radium nucleus: $E_\ell({}^{226}_{88}Ra) = 1{,}7311.10^3\,MeV$;
- The binding energy of the radon nucleus : $E_\ell({}^{222}_{86}Rn) = 1{,}7074.10^3\,MeV$;
- The binding energy of the helium nucleus: $E_\ell({}^{4}_{2}He) = 28{,}4\,MeV$;
- Decay constant of the radium: $\lambda = 1{,}4.10^{-11}\,s^{-1}$; 1year= 365,25 days;

0,25 **1-1-** Define the binding energy of a nucleus.

0,5 **1-2-** Choose, from the following statements, the one which is true

a- The radium and the radon are isotopes;

b- The radon nucleus consisting of 88 neutrons and 138 protons.

c- In a time equals $3t_{1/2}$ ($t_{1/2}$ is the half-life of the radium), the number of the radium nuclei equals 12.5% of its value at $t = 0$.

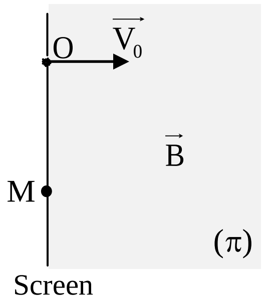
d- The relation between the half-life and the decay constant is : $t_{1/2} = \lambda.\ln 2$.

0,5 **1-3-** Show that: $1Ci \approx 3{,}73.10^{10}\,Bq$.

0,5 **1-4-** What would be in June 2018 the activity, in Bq unit, of 1g of radium's sample, knowing that its activity in June 1898 was 1Ci.

0,5 **1-5-** Calculate in MeV, the energy released (produced) by a decay of radium nucleus.

2- The α-particle produced passes through the gap O with the velocity $\vec{V_0}$ of horizontal direction, and penetrates in the region of the uniform magnetic field, of magnitude $B = 1{,}5\,T$, which is perpendicular to the vertical plan (π). This particle is deflected and hits the screen at the point M (see figure on the right).



The weight of the α-particle, of charge q=+2e, is negligible about the Lorentz force acting on it.

0,5 **2-1-** By applying Newton's second law, determine the nature of the motion of the α-particle in the uniform magnetic field $\vec{B}$.

0,5 **2-2-** Express the distance OM in terms of $m(\alpha)$, e , B, and V_0. Calculate its value.

We give: - Mass of the α-particle: $m(\alpha) = 6{,}6447.10^{-27}\,kg$;

- $V_0 = 1{,}5.10^7\,m.s^{-1}$; $e = 1{,}6.10^{-19}\,C$.

Exercise 2: Electricity (5 points)

The aim of this exercise is studying:

- The response of the RC circuit to a step of voltage,
- The response of the RL circuit to a step of voltage,
- The current electric resonance phenomenon in RLC circuit.

I- Response of the RC circuit to a step of voltage.

We set up the mounting shown in figure 1 which consists of:
- a power supply G of voltage, its electromotive force is E ;
- a resistor of resistance $R = 2\,k\Omega$;
- a capacitor of capacitance C, without initial charge;
- switch K;

At the instant t=0 the switch K is closed. We denote u_C the voltage between the terminals of the capacitor.

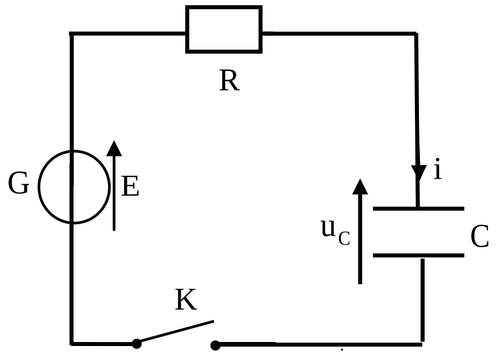


Figure 1

The curve shown in figure 2 represents the variations of $\frac{du_C}{dt}$ as a function of u_C.

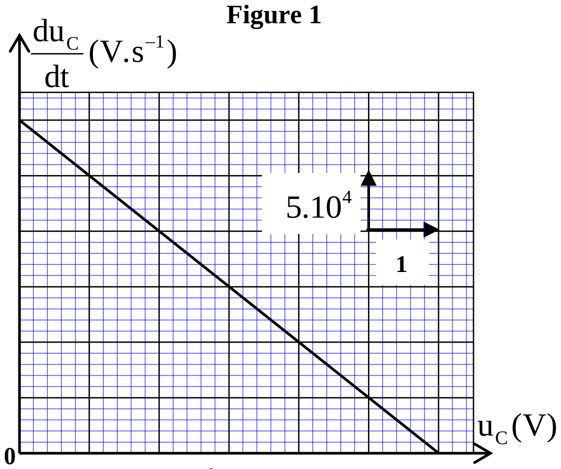


Figure 2

0,25 **1-** Find out the differential equation for the voltage u_C.

0,5 **2-** Determine the value of E and verify that $C = 10\,nF$.

0,25 **3-** We define the energetical yield of the charging process of the capacitor by the expression $\rho = \frac{E_e}{E_g}$ where E_e is the energy stored in the capacitor at the steady state, and $E_g = C.E^2$ is the energy delivered by the power supply G.
Determine the value of ρ.

II-Response of the RL circuit to a step of voltage

We set up the mounting shown in figure 3. It consists of:
- a power supply of voltage of e.m.f $E = 6V$.
- two resistors of resistance R_1 and $R_2 = 2\,k\Omega$;
- an inductor (b) of inductance L and of resistance $r = 20\,\Omega$;
- a switch K;
- an ideal diode D of knee of voltage (threshold) $u_S = 0$.

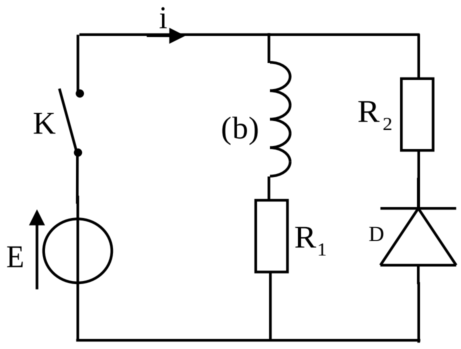


Figure 3

1- At an instant t=0, the switch K is closed. An appropriate datalogger gives the curve which represents the evolution of electric current i(t) flowing in the circuit(figure 4). The line (T) is the tangent of the curve at the instant t=0.

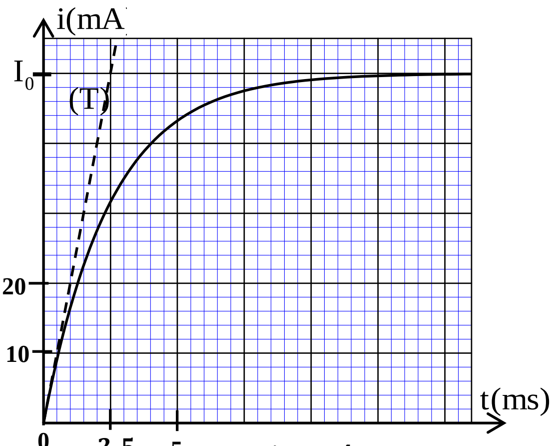


Figure 4

0,25 **1-1-**Find out the differential equation for i(t).

0,5 **1-2-** Compute the value of the resistance R_1 and verify that the value of the inductance of the inductor is $L = 0,3\,H$.

0,5 **1-3-** Calculate the voltage between the terminals of the inductor at the steady state.

2-When the steady state reaches, we open the switch K, at an instant t assumed as a new origin of time t=0.

0,5 **2-1-** Just after opening the switch K, what is the value of the electric current intensity? Justify your answer.

0,75 **2-2-** Based on the differential equation of the electric current intensity i(t), determine at the instant t=0 the value of $\frac{di(t)}{dt}$ and that of the voltage between terminals of the inductor.

0,25 **3-**At the moment of opening the switch, justify the role of the part of circuit which consists of the diode and the resistor of resistance R_2 .

III- Forced oscillations in RLC series circuit

We set up the RLC circuit which consists of the following components mounted in series:
- a low frequency generator, which delivers a sinusoidal alternating voltage u(t), of a constant effective voltage and adjustable frequency;
- the resistor of the resistance, $R_3 = 1980\Omega$;
- the previous inductor (b);
- the capacitor of capacitance C_1.

The experimental study gives the curve which represents the variations of the impedance Z of the RLC dipole as a function of the frequency N (figure 5).
We will take: $\sqrt{2} = 1,4$ and $\pi^2 = 10$.

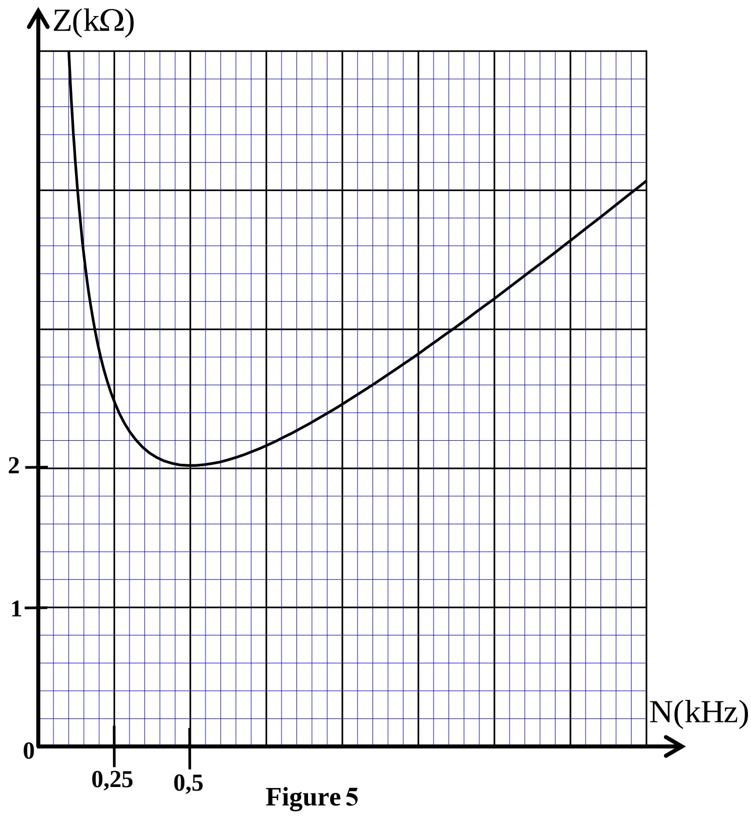


Figure 5

0,25 **1-** Determine the value of the resonance frequency.

0,5 **2-** Calculate the value of the capacitance of the capacitor C_1.

0,5 **3-**We denote by I_0 the maximum value of the effective intensity I of electric current which flows in the circuit.
For $I = \frac{I_0}{\sqrt{2}}$, find out the relationship between the impedance Z of the circuit and the resistance R_3 and r .
Deduce graphically the width of the passband -3db (bandwidth).

Exercise 3: Mechanics (4,75 points)

Part I and Part II are independent

Part I: study of the motion of an object in the air and in a liquid.

In swimming pools, we find diving boards from which the swimmers plunge into water.
In this part of the exercise, we study the motion of a diver, after he leaves the diving board, in the air and in the water.

The diver is modelled by an object (S) with center of inertia G and of mass m.
We study the motion of the center of inertia G of the object (S) in a frame of reference $R(O,\vec{k})$ linked to the earth assumed Galilean (figure 1)
Given: $m=80\,kg$; the gravitational field strength: $g=10\,m.s^{-2}$; we take $\sqrt{2}=1,4$.

1- Study of the motion of the center of inertia G in the air

After the diver leaves the diving board without initial velocity, at an instant of time assumed origin of time $(t_0=0)$, and before he hits the water, the motion in the air is assumed as free fall.
At the instant of time t_0, the center of inertia G is placed at the altitude $h=10\,m$ above the surface of water, and it coincides with the origin of the frame of reference $R(O,\vec{k})$ $(z_G=0)$ (Figure 1).

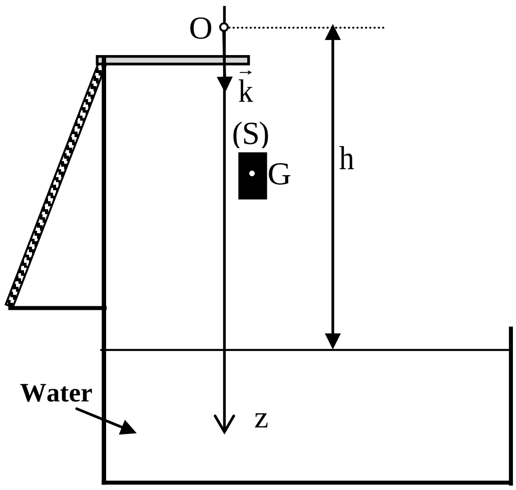


Figure 1

0,25 **1-1-** Find out the differential equation of the component v_z of the velocity of the center of inertia G.

0,5 **1-2-** Determine the fall time t_c of G in the air, and deduce its velocity v_e when G hits the water.

2- Study of the vertical motion of the center of inertia G in the water.

The diver hits the water with the velocity $\overrightarrow{v_e}$ of vertical direction. When he moves in water the path of the center G is vertical.
The object obeys to:
- The weight $\vec{P}$;
- A frictional fluid force: $\vec{f}=-\lambda.\vec{v}$, where $\vec{v}$ is the velocity of G at an instant t and λ is the coefficient of frictional fluid where $\lambda=250\,kg.s^{-1}$.
- The upthrust force (Archimedes' force) : $\vec{F}=-\dfrac{m}{d}.\vec{g}$ where g is the gravitational field strength and d=0.9 is the relative density of the diver.

The instant, when the diver hits the water, is assumed as a new origin of time (t=0), .

0,5 **2-1-** Establish the differential equation of the component v_z of G, we put $\tau=\dfrac{m}{\lambda}$.

0,5 **2-2-** Deduce the expression of the terminal velocity $v_{\ell z}$ in terms of τ, g , and d. Calculate its value.

0,5 **2-3-** The solution of the differential equation is $v_z(t)=A+Be^{-\frac{t}{\tau}}$, where A and B are constants. Express A in terms of $v_{\ell z}$, and B in terms of $v_{\ell z}$ and v_e.

0,25 **2-4-** Determine the instant t_r when the diver changes the sense of his motion (we assume that the diver doesn't reach the bottom of the swimming pool).

Part II: study of an elastic pendulum

The elastic pendulum studied in this part consists of a solid (S) with the center of inertia G and of mass m, which is attached to the end of a spring with non-contiguous turns and of length ℓ_0 when it is unstretched, its mass is negligible and its spring constant is K. The other end of the spring is fixed to a stand at the point P.

The solid (S) slides without frictions on the inclined rod (T) at an angle α to the vertical line. The rod is fixed at P (figure2).

We study the motion of the center of inertia G of the solid in a frame of reference $R(O,\vec{i},\vec{j})$ linked to the earth assumed Galilean.

We locate the position of G at one instant of time by the displacement x on the x-axis $(O,\vec{i})$.

At rest position, the center of inertia G of the solid coincides with the origin O of the frame of reference $(x_G = 0)$ (figure 2).

We take: $\pi^2 = 10$.

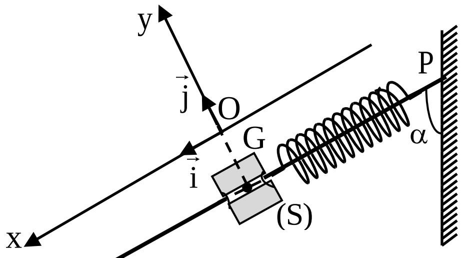


Figure 2

0,25 **1-** Express ℓ_e, the length of the spring at the rest point, in terms of ℓ_0, m, K, α and the gravitational field strength g.

2-We displace (S) from its rest position by the distance x_m, in the positive direction, and we release it at an instant $(t=0)$ without initial velocity.

The curve shown in figure 3 represents the variations of the acceleration a_x of the centre of inertia G as function of the displacement x where $-x_m \leq x \leq x_m$.

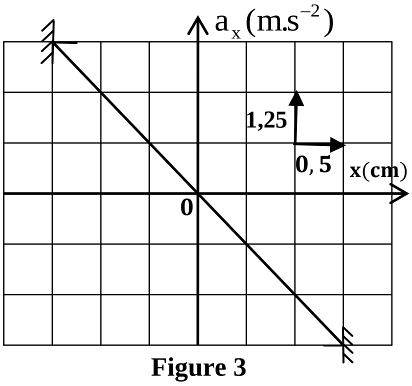


Figure 3

0,5 **2-1-** By applying Newton's second law; establish the differential equation of the displacement $x(t)$.

0,5 **2-2-** The solution of the differential equation is:

$$x(t) = x_m \cos\left(\frac{2\pi}{T_0}t + \varphi\right)$$

Find out the numerical expression of $x(t)$.

3- We choose the gravitational potential energy to be zero $(E_{pp}(O) = 0)$ on the horizontal plane passes through G at the equilibrium position (reference level) and the elastic potential energy E_{pe} to be zero $(E_{pe} = 0)$ when the spring is stretched at the equilibrium position.

0,5 **3-1-**Find out, in an instant t, the expression of the potential energy of the oscillating system $E_p = E_{pp} + E_{pe}$ in terms of x and K.

0,5 **3-2-**The curve shown in figure 4 represents the variation of the kinetic energy of the oscillator as a function of the displacement x.

Based on the conservation of the mechanical energy, determine the value of the spring constant K. Deduce the value of the mass m.

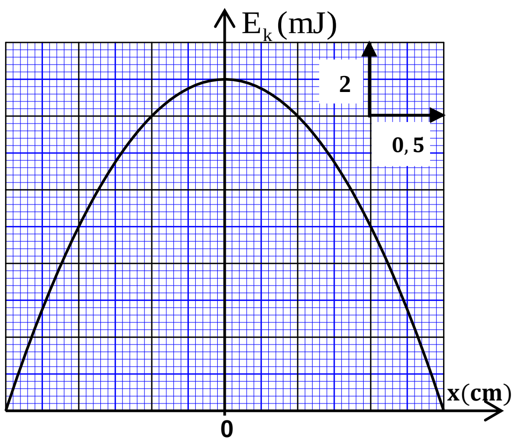


Figure 4