الامتحان الوطني الموحد للبكالوريا
المسالك الدولية
الدورة العادية 2020
- الموضوع –

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

المادة	الفيزياء والكيمياء	مدة الإنجاز	4
الشعبة أو المسلك	شعبة العلوم الرياضية (أ) و (ب) (خيار إنجليزية)	المعامل	7

*The use of the **non-programmable** scientific calculator is allowed.*

* *The literal formula must be given before the numerical application and the result must be accompanied by its unit.*

**The exercises can be treated separately according to choice of the candidate.*

The subject includes four exercises; one in Chemistry and three in Physics.

Exercise 1 : Chemistry (6,5 points)

First part **:** *Titration of the lactic acid in milk*

Second part : *Chromium-Silver electrochemical cell*

Exercise 2 : Waves (2,5 points) – Nuclear transformations (2,25 points)

I- *Diffraction of the light*

II- *Decay of the oxygen 15*

Exercise 3 : Electricity (5,5 points)

- *Charge of a capacitor*
- *Discharge of a capacitor through an inductor*
- *Forced oscillations in RLC series circuit*

Exercise 4 : Mechanics (3,25 points)

Part I **:** *Motion of a skier*

Part II : *Motion of a charged sphere in the gravitational field and in an electric field*

Exercise 1 : Chemistry (6,5 points)

The two parts are independent

First part : Titration of the lactic acid in milk

The acidity of milk increases by fermentation of lactic in case of bad conservation. The titration of the lactic acid of formula $CH_3-CHOH-COOH$ *allows, therefore, appreciating the state of conservation of milk.*
The lesser fresh the milk is, the more lactic acid it contains.

We propose to titrate the lactic acid presents in a cow's milk, which has not undergone any treatment, with an aqueous solution of sodium hydroxide. We will assume that the acidity of milk is due only to the lactic acid.
The lactic acid will be simply denoted by HA.

Given : - All measurements are performed at 25^0C;

- The ionic product of water: $K_w=10^{-14}$;

- Molar mass of the lactic acid is: $90\,g.mol^{-1}$;

1- Preparation of the aqueous solution of sodium hydroxide:

We prepare an aqueous solution (S_B) of sodium hydroxide $Na^+_{(aq)} + HO^-_{(aq)}$ of volume $V=1,0\,L$ and of molar concentration C_B, by dissolving a mass of caustic soda in distilled water. The measurement of the pH of the solution (S_B) gives $pH=12,70$.

1-1-Establish the expression of the pH of the solution (S_B) in terms of K_w and C_B. **(0,5pt)**

1-2-Verify that $C_B \simeq 5,0.10^{-2}\ mol.L^{-1}$. **(0,25pt)**

2-Control of the quality of a cow's milk

A laboratory technician titrates the acidity of a cow's milk. He performs the pH-metric titration by using an aqueous solution (S_B) of sodium hydroxide of molar concentration C_B. For this he introduces, in a beaker a volume $V_A=25,0\,mL$ of milk, then he gradually pours a volume V_B of the solution (S_B) and notes for each volume poured the pH of the reaction mixture.
We denote V_{BE} the volume of the solution of sodium hydroxide poured in the equivalence and K_A the acidity constant of the pair $HA_{(aq)}/A^-_{(aq)}$.

2-1- Write the chemical equation of the titration reaction. **(0,5pt)**

2-2- Establish the relationship used to determine the concentration C_A of lactic acid of milk in terms of V_A, C_B and V_{BE}. **(0,5pt)**

2-3- Establish the relationship: $V_B.10^{-pH}=K_A.(V_{BE}-V_B)$ with $0<V_B<V_{BE}$. **(0,75pt)**

2-4- The curve in figure 1 represents the variations of $10^{-pH}.V_B$ in function of V_B : $10^{-pH}.V_B=f(V_B)$.
With the help of the curve in figure1:

2-4-1-Determine the volume V_{BE} and deduce the concentration C_A. **(0,5pt)**

2-4-2-Determine the pK_A of the pair $HA_{(aq)}/A^-_{(aq)}$ **.(0,5pt)**

2-5- In the food industry, the acidity of milk is expressed in Dornic degree, denoted °D. One Dornic degree $(1°D)$ is equal to $1,0.10^{-1}$ g of lactic acid per liter of milk. Milk is considered fresh if it has an acidity between 15°D and 18°D. Can the milk studied be considered fresh? Justify the answer. **(0,75 pt)**

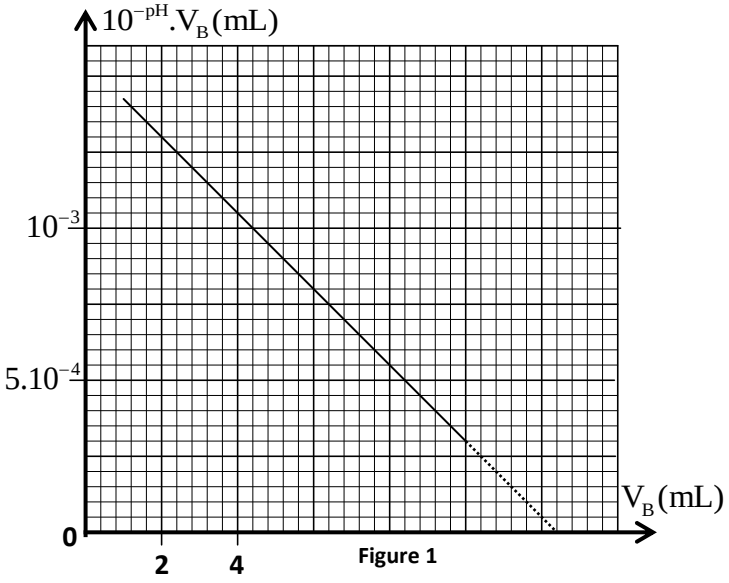


Figure 1

Second part: Chromium-Silver electrochemical cell

The Chromium-Silver electrochemical cell consists of two half-cells connected with a salt bridge. The half-cell (1) consists of chromium electrode immersed in a volume V=100 mL of an aqueous solution of chromium (III) nitrate $Cr^{3+}_{(aq)}+3NO^-_{3(aq)}$ of initial molar concentration $\left[Cr^{3+}_{(aq)}\right]_i = C_1 = 0,100\,mol.L^{-1}$. The half cell (2) consists of a silver electrode immersed in the volume V of an aqueous solution of silver nitrate $Ag^+_{(aq)} + NO^-_{3(aq)}$ of initial molar concentration $\left[Ag^+_{(aq)}\right]_i = C_1$.

Given:

- The pairs involved in the reaction : $Cr^{3+}_{(aq)}/Cr_{(s)}$; $Ag^+_{(aq)}/Ag_{(s)}$;

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

- The molar mass: $M(Cr) = 52\,g.mol^{-1}$.

We mount in series with the electrochemical cell a conductor (D), an ammeter (A) and a switch K.

At an instant of date $t_0 = 0$ we close the circuit, the ammeter indicates the flow of the electric current of positive constant intensity I_0 when the terminal COM is linked to the chromium electrode.

During the operation of the electrochemical cell, the mass of one of the electrodes decreases by 52mg after a period of $\Delta t = t_1 - t_0$ of operation.

1- Write the overall equation during the operation of the electrochemical cell**.(0,5pt)**

2- Determine the progress of the reaction of the operation of the electrochemical cell at the instant t_1 **.(0,5 pt)**

3- Deduce at the instant t_1 the molar concentration of chromium ions Cr^{3+} **. (0,5 pt)**

4- Knowing that the current intensity is $I_0 = 50\,mA$, find out the value of the instant t_1 . **(0,75 pt)**

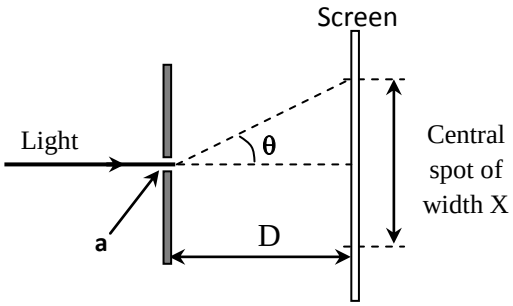
Exercise 2: Waves (2,5 points) – Nuclear Transformations (2,25 points)

I- Diffraction of the light

We take $c = 3.10^8 \, m.s^{-1}$ the speed of a light wave in the air.

The diagram in the figure bellow represents the experimental mounting for the study of the diffraction of the light.

A slit of width **a** is illuminated with laser light, red, of wavelength $\lambda_1 = 632,8\,nm$, then with a yellow light, by a mercury lamp, of unknown wavelength λ_2. On a screen located at the distance D from the slit, we visualize successively the patterns of obtained diffraction. With the red light, the width of the central spot is $X_1 = 6,0\,cm$ and with the yellow light the width is $X_2 = 5,4\,cm$.



1- Give the number of the false statements from the following: **(0,5 pt)**

a- the experience shown in the figure highlights the phenomenon of the dispersion of the light.

b- If a wave of wavelength λ passes through a slit of $a = \frac{\lambda}{2}$ in the same medium, then its speed changes.

c- If a wave of wavelength λ passes through a slit of $a = \frac{\lambda}{2}$ in the same medium, then its wavelength is divided by 2.

d- In a dispersive medium, if the wavelength of the wave decreases, then the speed of the signal increases.

2- We limit ourselves in the case of small angular deviations where $\tan\theta \approx \theta$ with θ is expressed in radian.

2-1- Give the expression used to determine the angle θ using exclusively the quantities shown in the figure. **(0,25pt)**

2-2- Show that the ratio $\frac{\lambda}{X}$ is constant for a given experimental device and deduce the wavelength λ_2. **(0,75pt)**

3- If we perform the same experiment by using the white light, we observe a white central spot and iridescent lateral spots. Interpret the appearance of the observed figure. **(0,5pt)**

4- Calculate the wavelength of the red light of the used laser when it propagates in a medium of refractive index $n = 1,5$ as well as its speed of propagation in this medium. **(0,5pt)**

II-Decay of the oxygen 15

The positron emission tomography (PET), (In French TEP «tomographie par émission de positrons »), is a medical scanning technique practiced in nuclear medicine which allows to obtain precise 3D images of some organs of the body which can be affected by diseases like cancer.

Among the radioactive substances used we can cite the fluorine, the oxygen, the nitrogen…

In this exercise we use the oxygen 15($^{15}_{8}O$) which is one of the oxygen isotopes.

In PET, we detect the water molecules (found in large quantities in the brain) using the radioactive water (the oxygen 15 ($^{15}_{8}O$) labeled water) which is injected into the subject intravenously.

Oxygen 15 decays to nucleus ${}^{A}_{Z}X$ with the emission of a positron.

Given: - Avogadro constant: $N_A = 6,022.10^{23}\ mol^{-1}$; $1u = 931,494\ MeV.c^{-2}$;

- Molar mass of water de : $M = 18\ g.mol^{-1}$; Density of water : $\rho = 1\ g.cm^{-3}$;
- The masses: $m({}^{A}_{Z}X) = 15,000109\ u$; $m({}^{15}_{8}O) = 15,003066\ u$; $m({}^{0}_{1}e) = 5,486.10^{-4}\ u$;
- The Half-life of the oxygen 15: $t_{1/2} = 122\ s$.

1- Write the equation of the decay reaction of the nucleus of oxygen 15(${}^{15}_{8}O$)by determining A and Z.**(0,5 pt)**

2- Determine, in MeV unit, $|\Delta E|$ the energy released by one nucleus of oxygen 15. **(0,5 pt)**

3- Admitting that the volume of the injection of initial activity $a_0 = 3,7.10^7\ Bq$ is $V = 5\ cm^3$, find out the proportion of molecules of labeled water in the injection. **(0,75 pt)**

4- To continue the PET examination, we assume that a new injection is necessary when the activity $a(t_1)$ of the remaining nucleus of oxygen 15 at the instant of date t_1 is of order of $0,15\%$ of initial activity a_0 of the injection at $t = 0$.

Justify, by calculation, that we can make a new injection after a time close to $t = 20\ min$. **(0,5 pt)**

Exercise 3 : Electricity(5,5 points)

The components such as resistors, capacitors, conductors, diodes … are used in different circuits of electric apparatus and electronics…

In this exercise, we propose to study,

- the response of the RC to an increasing step of voltage;
- the free and the forced oscillations in RLC series circuit.

We perform the mounting shown in figure 1 which consists of:

- An ideal generator of voltage of e.m.f E ;
- A resistor of variable resistance R ;
- A capacitor of capacitance C , without initial charge;
- A switch K;
- An inductor (b) of inductance L and of resistance $r = 12\ \Omega$.

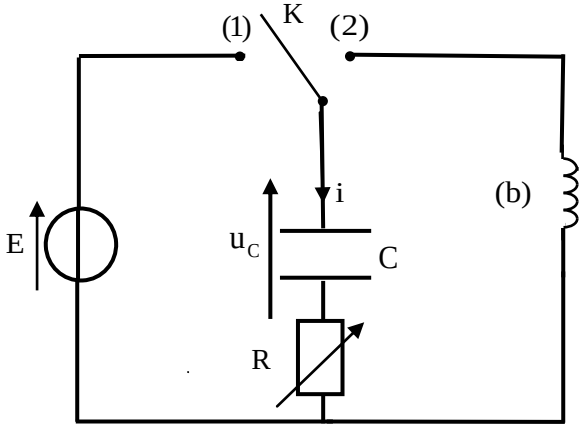


Figure 1

1- Charge of the capacitor

We adjust the value of the resistance R to the value $R = R_0 = 40\Omega$.

At an instant t=0, we put the switch K at position (1).

1-1- Establish the deferential equation verified by the charge $q(t)$ of the capacitor. **(0,5pt)**

1-2- The curve of figure 2 represents the variations of the intensity $i(t)$ in function of $q(t)$.

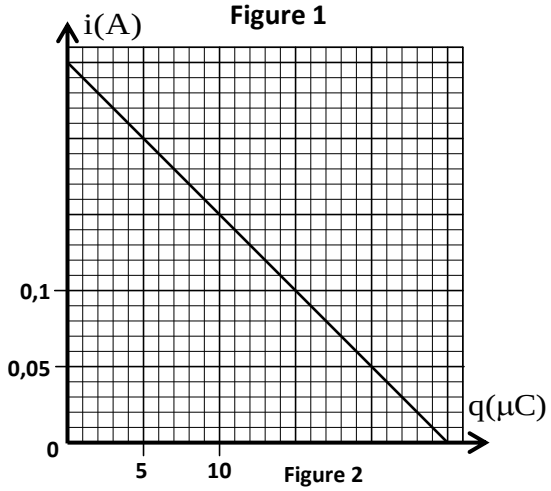


Figure 2

With the help of the graph of figure 2, find out :

1-2-1-The value of E. **(0,25pt)**

1-2-2- The value of the time-constant. **(0,5pt)**

1-3-Verify that $C = 2,5\mu F$. **(0,25pt)**

2- Discharge of a capacitor through the inductor

2-1- We adjust the value of the resistance R to a value R_1.

When the steady state is reached; we switch the switch K in position (2), at an instant t chosen as a new origin of dates $(t = 0)$. A suitable computing system allowed to draw the curve representing the charge $q(t)$ of the capacitor (figure 3).

2-1-1- show that the deferential equation governing the evolution of the charge $q(t)$ of the capacitor is written as: $\frac{d^2q(t)}{dt^2} + A.\frac{dq(t)}{dt} + B.q(t) = 0$ where A and B are two positive constants. **(0,5pt)**

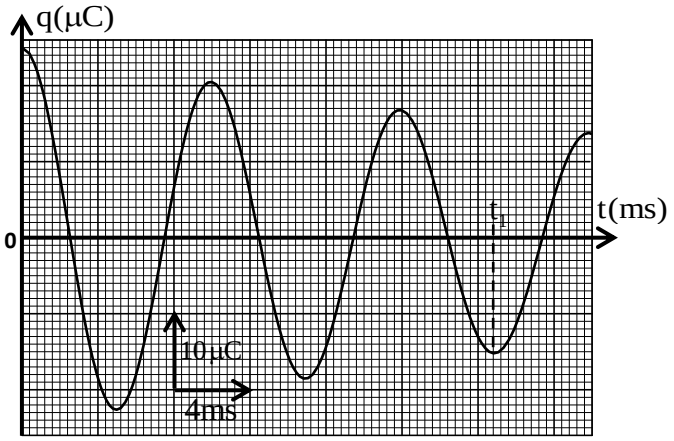


Figure 3

2-1-2- Determine the value of the voltage between the terminals of the inductor just after the switch of the switch K to position (2) **. (0,25pt)**

2-1-3- Considering that the value of the pseudo-period of the oscillations is equal to the natural period of the LC circuit, verify that $L = 1,0\,H$. (We take $\pi^2 = 10$).**(0,25pt)**

2-1-4- Calculate the energy dissipated by joule effect in the circuit between the instant $t = 0$ and the instant t_1 indicated in figure 3**.(0,5pt)**

2-2- we vary the resistance R, and we observe that for $A > 2\sqrt{B}$ the state of the oscillation is overdumped. In this case the total resistance of the circuit is greater than a value R_c.

By using the dimensional equations, verify that the expression of R_c has a dimension of a resistance and determine the minimum value of R. **(0,75pt)**

3- The forced electric oscillations in RLC series circuit

We supply the circuit, consisted of the dipoles previously used (the inductor (b), the resistor of variable resistance R and the capacitor of the capacitance C), by a generator GBF delivering a sinusoidal alternating voltage $u(t) = U_m \cos(2.\pi.N.t + \varphi)$ of variable frequency N (figure 4).

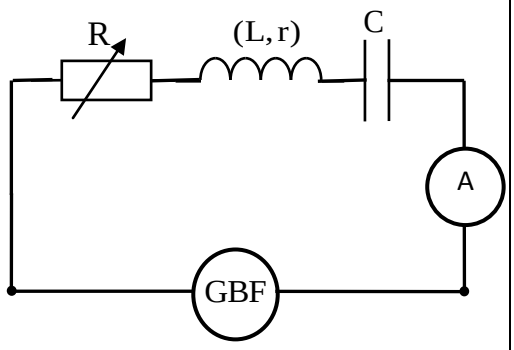


Figure 4

The intensity of the current flowing in the circuit is written as: $i(t) = I_m \cos(2.\pi.N.t)$.

We adjust the value of the resistance R to the value R_2.

We display, with the help of a suitable computing system, the voltage $u_R(t)$ between the terminals of the conductor on

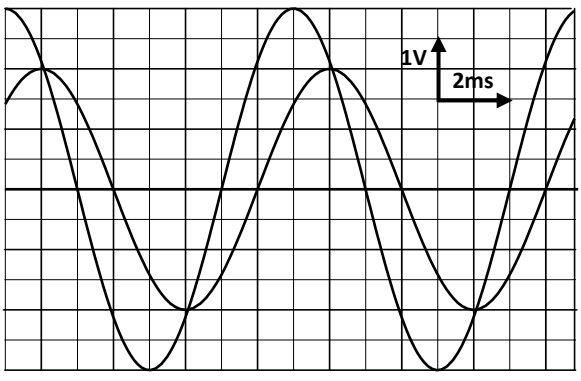


Figure 5

the channel Y_A and the voltage $u(t)$ between the terminals of the generator on the channel Y_B.
We obtain the oscillogram shown in figure 5.

3-1- Determine the intensity indicated by the ammeter knowing that the measured impedance of the circuit is $Z \simeq 390,4\Omega$.**(0,5pt)**

3-2- Calculate the value of R_2 . **(0,5pt)**

3-3- Write the numerical expression of the voltage $u(t)$.**(0,75pt)**

Exercise 4: Mechanics (3,25 points)

Parts I and II are independent.

Part I: Study of the motion of a skier

In this part, we study the motion of a skier on an inclined plane in two stages:

- **First stage:** The frictional fluids force of the air is negligible,
- **Second stage:** The frictional fluids force of the air is not negligible,

A skier slides on the runway inclined at an angle $\alpha = 45^\circ$ to the horizontal plane (figure1).
The skier and his accessories are modeled as solid (S) of mass $m = 75\,kg$ and of center of inertia G.
We study the motion of the center of inertia G in the orthonormal frame of reference $(O,\vec{i},\vec{j})$ linked to the earth assumed Galilean.
At the instant t=0, the skier starts without initial velocity. At this instant, G coincides with the origin O of the frame of reference $(O,\vec{i},\vec{j})$ (figure1).
We take the gravitational field strength: $g = 10\ m.s^{-2}$ and we neglect the action of the upthrust force.

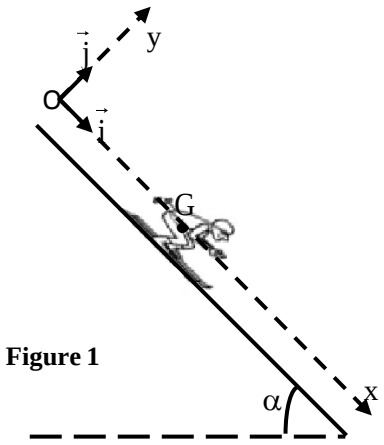


Figure 1

1- First stage: The motion of the skier without frictional fluids

The contact between the inclined runway and the solid (S) occurs with solid friction. The runway acts on the skier by the force $\vec{R}$ which has a tangential component $\vec{T}$ and a normal component $\vec{N}$. During the motion of the skier the magnitude of $\vec{T}$ and that of $\vec{N}$ are linked by the relation $T = k.N$ where k is a constant.

1-1- By applying Newton's second law, express the acceleration of G in terms of g, α and k .**(0,5pt)**

1-2- The curve shown in figure 2, represents the evolution of the velocity v of the center of inertia G in function of time. Determine graphically the acceleration.**(0,25pt)**

1-3-Check that $k \approx 0,9$.**(0,25pt)**

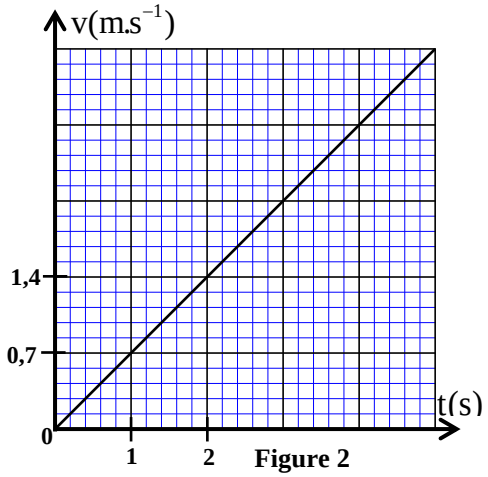


Figure 2

2- Second stage: Study of the motion of the skier with frictional fluids

In addition to the same forces acting on the solid (S) in the first stage, (S) obeys to a frictional fluids force due to the air, which is modeled by the force $\vec{F} = -\lambda\vec{v}$, where v is the velocity of the center of inertia G at an instant t and λ is a positive constant of value $\lambda = 5$ SI units.

2-1- Applying Newton's second law, show that the differential equation for the velocity of G is: $\frac{dv}{dt} + A.v + B = 0$ with $\vec{v} = v\vec{i}$, and A and B are two constants.**(0,5pt)**

2-2- Determine the value of the terminal velocity v_ℓ of the motion.**(0,25pt)**

2-3- With the help of the table on the right, and using Euler's method, determine the velocity v_2 of the motion of (S). (The step of the calculation is $\Delta t = t_2 - t_1$).**(0,5pt)**

t(s)	$v(m.s^{-1})$	$a_G(m.s^{-2})$
$t_1 = 14$	$v_1 = 6,30$	a_1
$t_2 = 15,4$	v_2	a_2

Part II: Motion of a charged sphere in the gravitational field and in an electric field

Two vertical metal plates (A) and (C) are placed in the vacuum at a distance d from each other and are supplied with a positive voltage $V_A - V_C = U_0$. The length of each plate is ℓ . Between the two plates there is a uniform electric field $\vec{E}$ (figure 3).

A small sphere (S) of mass m, carrying a positive charge q, is abandoned without initial velocity at the instant t=0 at a point M_0.

We study the motion of the centre of inertia G of the sphere (S) in an orthonormal frame of reference $R(O,\vec{i},\vec{j})$ linked to the earth assumed Galilean. The coordinates of the point M_0 in the frame of reference $R(O,\vec{i},\vec{j})$ are $(x_0 = \frac{d}{2}; y_0 = \ell)$ (figure 3).

Between the two plates in addition to its weight, the sphere obeys to the electrostatic force $\vec{F} = q\vec{E}$.

Given: $g = 10\,m.s^{-2}$; $\ell = 1m$; $d = 4cm$; $\alpha = \frac{q}{m} = 10^{-6}\,C.kg^{-1}$.

Remember that: $E = \frac{U_0}{d}$.

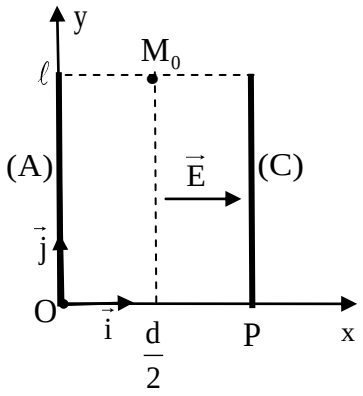


Figure 3

1- By applying Newton's second law, establish the parametric equations of the motion x(t) and y(t) of the centre of inertia G in terms of U_0 and of t (in SI units). **(0,5 pt)**

2- Deduce the equation of the path of the sphere. **(0,25 pt)**

3- For a determined value of voltage U_0, the path of the sphere passes through the point P of coordinates $(d,0)$. Show that $U_0 = 8kV$. **(0,25 pt)**

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