الامتحان الوطني الموحد للبكالوريا
المسالك الدولية
الدورة العادية 2022
– الموضوع –

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المملكة المغربية
وزارة التربية الوطنية
والتعليم الأولي والرياضة
المركز الوطني للتقويم والامتحانات

3h	مدة الإنجاز	الفيزياء والكيمياء	المادة
7	المعامل	شعبة العلوم التجريبية: مسلك العلوم الفيزيائية - خيار إنجليزية	الشعبة أو المسلك

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

Literal expressions should be given before doing numerical calculations.

This exam paper consists of four exercises

Exercise 1 (7 points):

- Chromium-electroplating a steel plate by electrolysis
- Study of some properties of an aqueous solution of the propanoic acid

Exercise 2 (3,5 points):

- Sound waves
- Disintegration of the iodine-131

Exercise 3 (4,5points):

- Response of the RC dipole to a step voltage
- Free oscillations in a RLC series circuit

Exercise 4 (5 points):

- Study of the fall of a ball in a viscous liquid
- Study of the motion of an artificial satellite

Marking scale

EXERCISE 1 (7 points)

Part 1 and part 2 are independent

Part 1 : Chromium-electroplating a steel plate by electrolysis

The electrolysis is the process of converting electric energy into chemical energy. Electroplating objects with a thin layer of a metal and protecting them against the corrosion are some uses of the electrolysis.

In this part, we suggest the study of the chromium-electroplating a steel plate by electrolysis.

Given :

- Redox pairs involved are : $Cr^{3+}_{(aq)} / Cr_{(s)}$ and $O_{2(g)} / H_2O_{(\ell)}$
- $1F = 96500\,C.mol^{-1}$
- Molar mass of the chromium : $M(Cr) = 52\,g.mol^{-1}$

To perform this electrolysis, we immerse totally a steel plate in an aqueous solution of the chromium (III) chloride $Cr^{3+}_{(aq)} + 3Cl^{-}_{(aq)}$ and we connect it to one pole of a generator G. the other pole of the generator is connected to a graphite electrode (figure1). We switch on the circuit, an electric current of constant intensity $I = 2\,A$ flows in the circuit. We observe that the oxygen $O_{2(g)}$ is released at the graphite electrode and a uniform layer of the chromium is deposited on the steel plate.

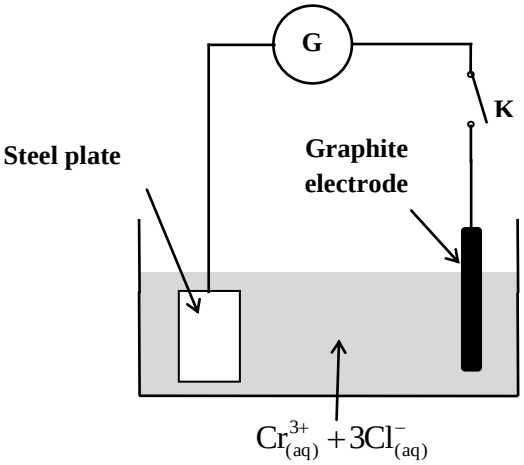


Figure1

0,5 **1.** Identify which electrode is the cathode. Justify your answer.

2. Copy the number of the question and choose the correct answer from the proposals.

0,5 **2.1.** The equation for the reaction occurring at the graphite electrode is written as :

A	$2H_2O_{(\ell)} \rightleftarrows O_{2(g)} + 4H^{+}_{(aq)} + 4e^{-}$	**B**	$Cr^{3+}_{(aq)} + 3e^{-} \rightleftarrows Cr_{(s)}$
C	$2O^{2-}_{(aq)} \rightleftarrows O_{2(g)} + 4e^{-}$	**D**	$2H_2O_{(\ell)} \rightleftarrows O_{2(g)} + 2H_{2(g)}$

0,5 **2.2.** The equation for the reaction occurring at the steel plate is written as :

A	$2H_2O_{(\ell)} \rightleftarrows O_{2(g)} + 4H^{+}_{(aq)} + 4e^{-}$	**B**	$Cr^{3+}_{(aq)} + 3e^{-} \rightleftarrows Cr_{(s)}$
C	$Cr^{2+}_{(aq)} + 2e^{-} \rightleftarrows Cr_{(s)}$	**D**	$2H_2O_{(\ell)} \rightleftarrows O_{2(g)} + 2H_{2(g)}$

0,75 **3**. The duration of this electrolysis is $\Delta t = 2\,h$. Determine the mass m(Cr) of chromium deposited on the steel plate.

Part 2 : Study of some properties of an aqueous solution of the propanoic acid

The propanoic acid of formula $C_2H_5 - COOH$ can be used as a food conservator and in the manufacture of the anti-inflammatory drugs. The propanoic acid is also involved in many organic synthesises.

The objective of this part is to study some properties of an aqueous solution of the propanoic acid.

1. Aqueous solution of the propanoic acid

We prepare an aqueous solution S_a of the propanoic acid of concentration $C_a = 5.10^{-2}\,mol.L^{-1}$.

The measurement of the pH of the solution S_a gives $pH = 3,1$.

0,5 **1.1.** Write the equation for the reaction between the propanoic acid and water.

0,75 **1.2.** Calculate the final progress rate τ of this reaction. What can you deduce?

0,75 **1.3.** Express the reaction quotient at equilibrium $Q_{r,eq}$ associated to the equation of the previous reaction in terms of C_a and $\left[H_3O^+_{(aq)}\right]_{eq}$. Calculate its value.

0,5 **1.4.** Deduce the value of pK_A of the pair $C_2H_5COOH_{(aq)} / C_2H_5COO^-_{(aq)}$.

2- Titration of the solution of the propanoic acid

To verify the value of the concentration C_a of the solution S_a, we perform the pH-metric titration of a volume V_a= 20mL of the solution S_a by an aqueous solution S_b of the sodium hydroxide $Na^+_{(aq)} + HO^-_{(aq)}$ of molar concentration $C_b = 5.10^{-2}\,mol.L^{-1}$.

In figure 2, we represent the curve of the pH variations of the reaction mixture as a function of the volume V_b added from the solution S_b and the curve $\frac{dpH}{dV_b} = f(V_b)$.

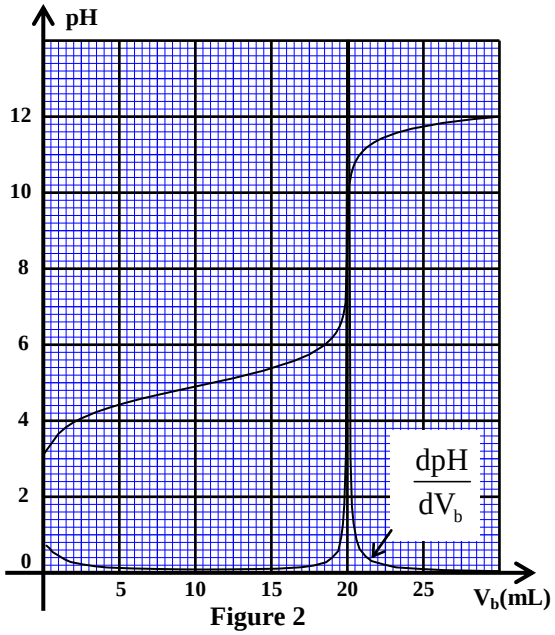


Figure 2

0,5 **2.1.** Write the equation for the reaction of titration.

0,25 **2.2.** Determine graphically the volume V_{bE} of the solution S_b added at the equivalence.

0,5 **2.3.** Verify the value of the concentration C_a.

0,5 **2.4.** We prepare the solution S_a by diluting 10 times an aqueous solution S_0 of the propanoic acid. Determine the mass m of the propanoic acid dissolved in one litre of the solution S_0.

Given : The molar mass of the propanoic acid is $M = 74\,g.mol^{-1}$.

0,5 **2.5.** For a volume $V_b = 5\,mL$ of the solution S_b added, determine the percentage of the acid of the pair $C_2H_5COOH_{(aq)} / C_2H_5COO^-_{(aq)}$ in the reaction mixture.

EXERCISE 2 (3,5 points)

Part 1 and part 2 are independent

Part 1: Propagation of sound waves in the air

To determine the wave speed of sound waves in the air, we perform the experimental set-up in figure 1. This set-up is consisted of a transmitter E and of a receiver R of sound waves distance $L = 85\,cm$ from each other. E emits a sound wave, it propagates in the air, and then R receives it.

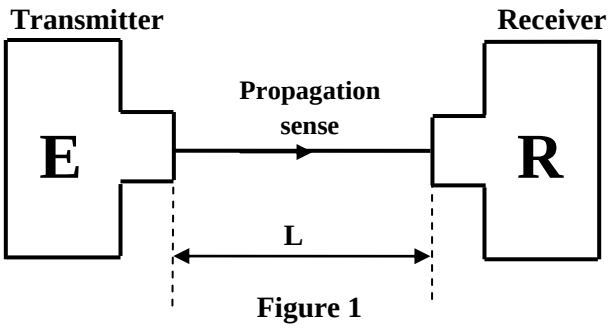


Figure 1

A datalogger is used to visualise both the emitted signal (a) and the received signal (b) (figure 2).

1. Copy the number of the question and answer by true or false.

0,25 **1.1.** The sound wave is a transverse wave.

0,25 **1.2.** The sound wave does not propagate in vacuum.

0,25 **2.** Determine the duration Δt taken to reach the receiver R.

0,5 **3.**Calculate the wave speed v of the sound waves in the air.

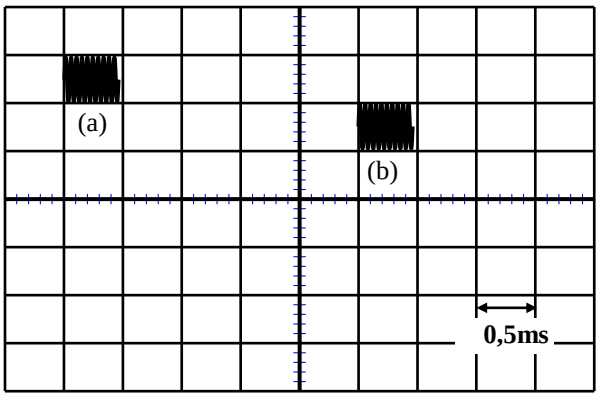


Figure 2

Part 2 : Disintegration of the iodine-131

The iodine-131 ($^{131}_{53}I$) *is radioactive of* β^- *type.*

The iodine can be used in small doses for medical purposes such as the diagnostic of the thyroid gland dysfunction and the treatment of some diseases relating to this gland.

The disintegration of the iodine-131 gives a nucleus $^{A}_{Z}X$.

In this part, we suggest studying the disintegration of the iodine-131.

Given :

Element	Tellurium		Xenon		Cesium	
Some isotopes of the element	$^{131}_{52}Te$	$^{132}_{52}Te$	$^{130}_{54}Xe$	$^{131}_{54}Xe$	$^{127}_{55}Cs$	$^{132}_{55}Cs$

- Mass of the iodine-131 nucleus: $m(^{131}_{53}I) = 130,906125\ u$;
- Mass of the nucleus $^{A}_{Z}X$: $m(^{A}_{Z}X) = 130,905082u$;
- Mass of the particle β^- : $m(\beta^-) = 5,48580.10^{-4}u$;
- Atomic mass unit : $1u = 931,5\,MeV.c^{-2}$.

0,5 **1.** Write the equation for the disintegration of the iodine-131 by identifying $^{A}_{Z}X$ the produced nucleus.

0,5 **2.** Calculate, in MeV, the released energy E_{pro} produced by the disintegration of the iodine-131 nucleus.

3. At an instant taken as origin of time t = 0, a patient gets a dose of the iodine-131 solution of activity a_0.

The curve in figure 3 represents the variations of the activity a(t) of this dose as a function of time.

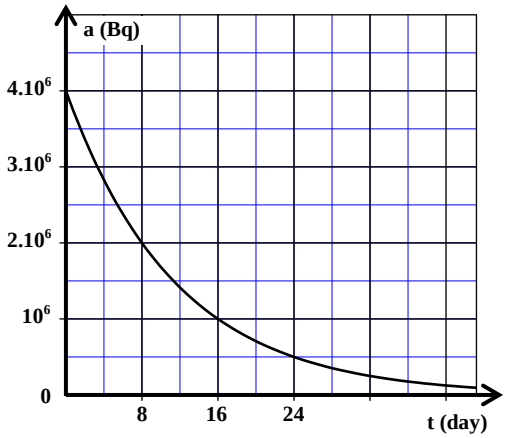


Figure 3

0,25 **3.1.** Determine graphically the half-life $t_{1/2}$ of the iodine-131.

0,5 **3.2.** Calculate N_0 the number of the iodine-131 nuclei present in the dose at t = 0.

0,5 **3.3.** By using the radioactive decay law, determine, in days, the instant t_1 when 95% of the iodine-131 nuclei are disintegrated.

EXERCISE 3 (4,5 points)

This exercise aims at :

- determining the capacitance of a capacitor ;
- determining the inductance of an inductor ;
- doing the energetic study of the RLC series circuit.

We perform the electric set-up in figure 1. This set-up is consisted of the following components:
- an ideal power supply of voltage of electromotive force E;
- a capacitor of capacitance C initially discharged;
- an inductor of inductance L and of resistance r;
- a resistor of resistance R;
- a double switch K.

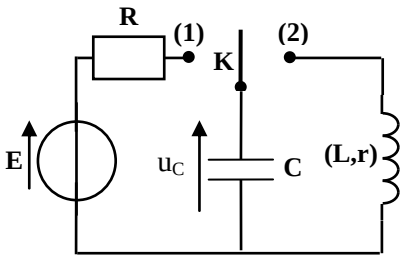


Figure 1

1. Response of the RC dipole to a step of voltage

At an instant taken as origin of time $t = 0$, we put the switch K at position (1).The curves (C_1) and (C_2) in figure 2 represent the evolution of the voltage $u_C(t)$ between terminals of the capacitor and the evolution of the intensity i(t) of the electric current which flows in the circuit.
(T) is the tangent of the curve (C_1) at the point of time $t = 0$.

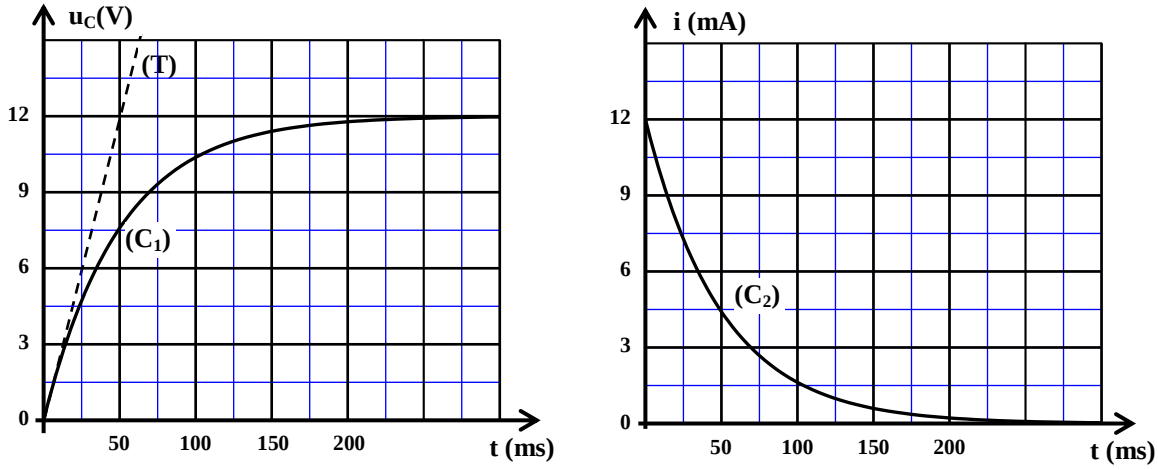


Figure 2

0,25 **1.1.** Show that the differential equation of the voltage $u_C(t)$ is written as : $\frac{du_C}{dt} + \frac{1}{R.C}u_C = \frac{E}{R.C}$

1.2. The solution of this differential equation is : $u_C(t) = E(1 - e^{\frac{-t}{RC}})$.

0,5 **1.2.1.** Find out the expression of the electric current intensity i(t) in terms of E, R, C and t.

0,5 **1.2.2.** By exploiting the curves in figure 2, determine the value of R.

0,25 **1.2.3.** Show that the capacitance C of the capacitor is : $C = 50\mu F$.

2. Free oscillations in a RLC series circuit

When the capacitor of capacitance $C = 50\mu F$ is fully charged, we placed the switch K at position (2) at an instant taken as a new origin of time $t = 0$. This capacitor discharges through the inductor of inductance L and of resistance r (figure 1).

2.1. First case :

In this case, we suppose that the resistance of the inductor is negligible.

0,25 **2.1.1.** Show that the differential equation of the voltage $u_C(t)$ is written as : $\frac{d^2u_C}{dt^2} + \frac{1}{LC}.u_C = 0$.

0,5 **2.1.2.** Choose from the following curves (C_1) and (C_2) and (C_3) in figure 3 (page 6/8), which one represents the evolution of the voltage $u_C(t)$. Justify your answer.

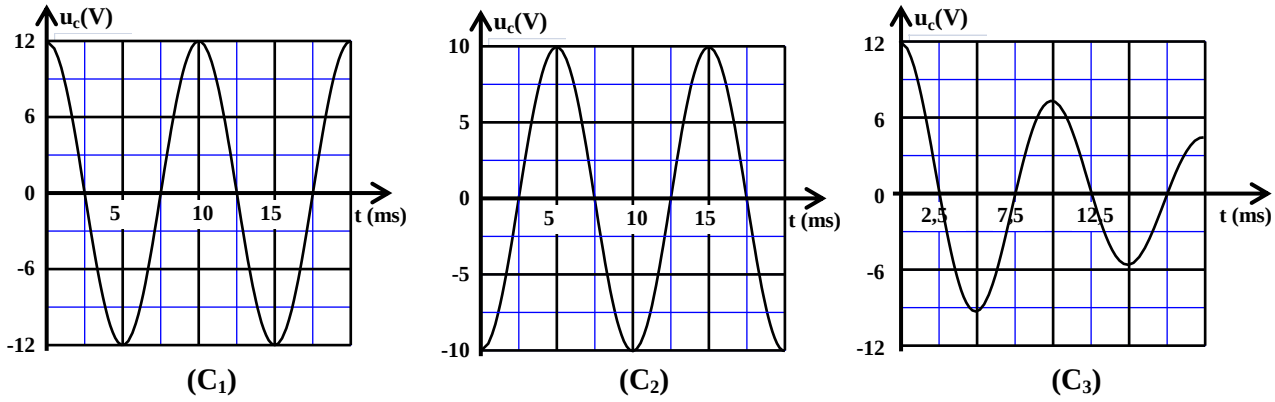


Figure 3

2.1.3. The solution of the previous differential equation is : $u_c(t) = U_0 \cos\left(\frac{2\pi}{T_0} t\right)$ where U_0 is the maximum value of the voltage and T_0 is the natural period of the oscillations.

0,5 **a-** Find out the expression of T_0 in terms of L and C.

0,5 **b-** Show that the value of the inductance is : $L = 0,05\,H$. (take $\pi^2 = 10$).

2.2. Second case :

In fact, the resistance of the inductor is not negligible. In this case and by using a datalogger, we visualise the curves of the evolution of the voltage $u_C(t)$ between terminals of the capacitor and the evolution of the intensity of the electric current $i(t)$ which flows through the circuit (figure 4).

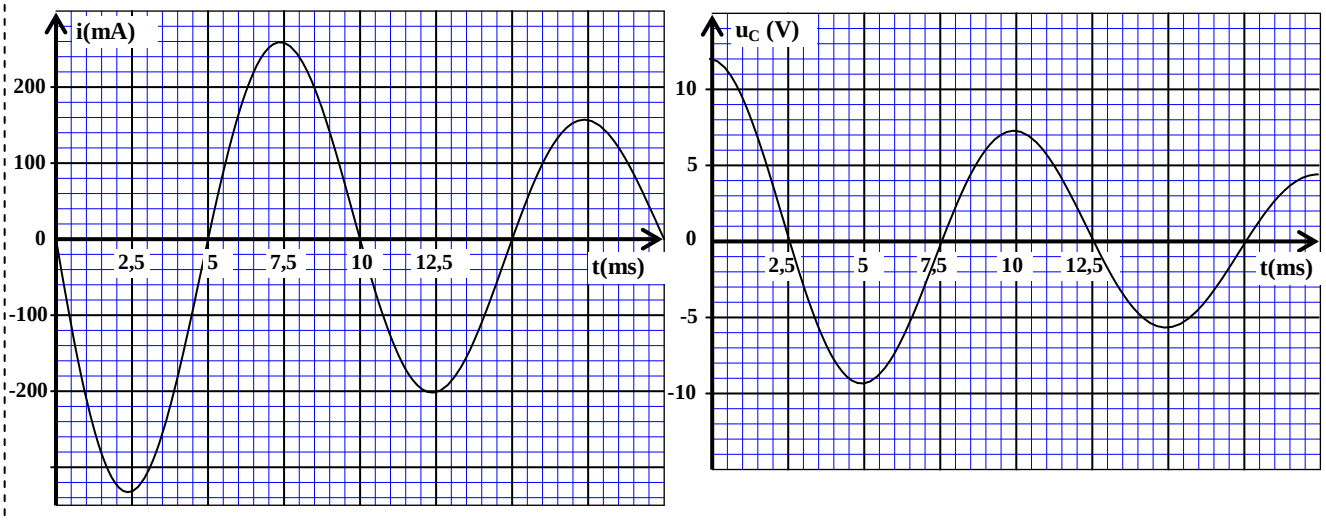


Figure 4

0,5 **2.2.1.** Write the expression of the total energy E_t of the circuit in terms of C, $u_C(t)$, L and i(t).

0,75 **2.2.2.** By exploiting the curves in figure 4, calculate the dissipated energy ΔE in the circuit between the instants $t_0 = 0$ and $t_1 = 9\,ms$.

EXERCISE 4 (5 points)

Part 1 and part 2 are independent

Part 1: Study of the fall of a ball in a viscous liquid

In this part, we suggest determining the density ρ_r of the ricin oil.

We get off without initial velocity a homogenous steel ball in a cylinder filled with the ricin oil.

This ball is of mass m and of density ρ_a.

We study the motion of the center of inertia G of the ball in the coordinate system $(O,\vec{k})$ linked to an Earth frame of reference assumed Galilean (figure 1).

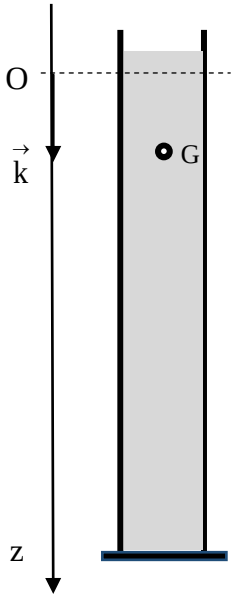


Figure1

Over this vertical falling in the liquid, the ball obeys three forces:

- its weight $\vec{P}$.

- the upthrust (Archimedes' force) $\vec{F}_a$ is of vertical direction, of upward sense and of magnitude $F_a = \rho_r.V.g$ where V is the volume of the ball and g is the gravitational acceleration.

- the viscous frictional force which is modeled with the vector $\vec{F} = -k.\vec{v}$ where k is a positive constant and $\vec{v}$ is the velocity of G at an instant t.

A datalogger permits plotting the curve in figure 2 which represents the evolution of the speed v(t).

(T) is the tangent of the curve at the point of time t=0.

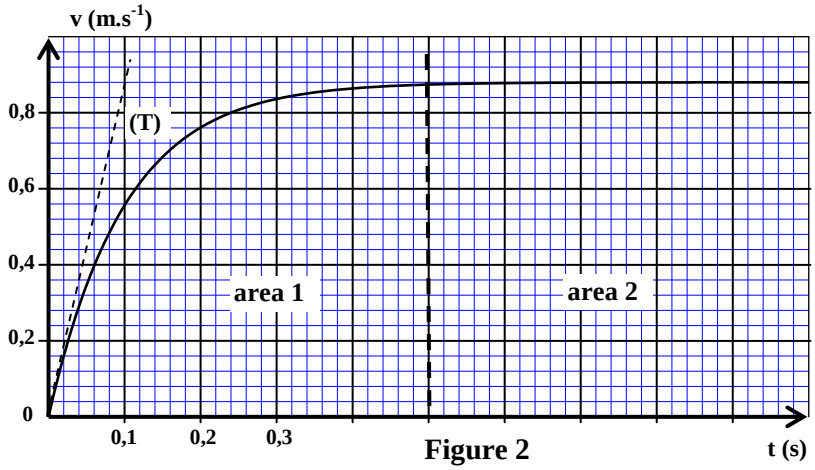


Figure 2

Given : $m = 10\ g$; $\rho_a = 7,8\ g.cm^{-3}$; $g = 10\ m.s^{-2}$.

0,5 **1**. The curve in figure 2 includes two areas. Determine for each area, the corresponding state.

0,75 **2.** By applying Newton's 2nd law, show that the differential equation of the motion of G is written as : $\frac{dv}{dt} + \frac{1}{\tau}.v = g(1 - \frac{\rho_r}{\rho_a})$ where τ is the characteristic time of the motion that to be expressed in terms of m and k.

3. Determine graphically,

0,5 **3.1.** the value of τ then deduce, in SI units, the value of k.

0,25 **3.2.** the value of the terminal speed V_ℓ.

0,75 **4**. Find the expression of the density ρ_r of the ricin oil in terms of τ, g, ρ_a and V_ℓ. Calculate its value.

Part 2: Study of the motion of an artificial satellite

Many artificial satellites orbit the Earth for a variety of purposes such as weather forecasting, telecommunication, scientific researches and borders observation…

The objective of this part is to study some physical quantities characterising the motion of an artificial satellite around the Earth.

We study the motion of an artificial satellite S of mass m_s in a geocentric frame of reference assumed Galilean.

We assume that the Earth presents a uniform spherical mass.

All other forces are negligible to the universal attraction force exerted by the Earth on this satellite and its dimensions are negligible to the distance of the center of the Earth.

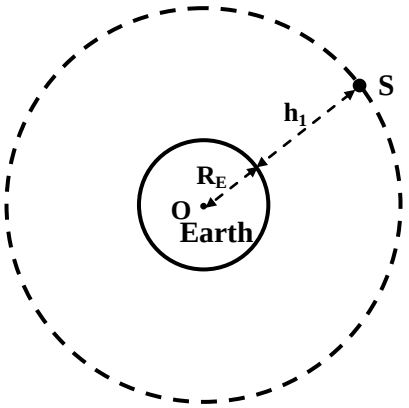


Figure 3

Given :

- Masse of the Earth: $M_E = 5{,}97.10^{24}$kg;
- Radius of the Earth : $R_E = 6380$ km ;
- Gravitational constant : $G = 6{,}67.10^{-11}\,N.m^2.kg^{-2}$.

1. This satellite is placed at a circular orbit of center O and of radius $r = R_E + h_1$ where h_1 = 1000 km (figure 3).

0,5 **1.1.** Choose the correct answer from the proposals.

The expression of the magnitude of the universal attraction force exerted by the Earth on the satellite is :

A	$F_{E/S} = G\dfrac{M_E.m_S}{h_1^2}$	**B**	$F_{E/S} = G\dfrac{M_E.m_S}{(R_E+h_1)^2}$	**C**	$F_{E/S} = G\dfrac{M_E.m_S}{R_E^2}$	**D**	$F_{E/S} = G\dfrac{(M_E.m_S)^2}{(R_E+h_1)^2}$

0,5 **1.2.** By applying the Newton's 2nd law, show that the expression of the speed v of the satellite is : $v = \sqrt{\dfrac{G.M_E}{R_E+h_1}}$.

0,5 **1.3.** Verify that the orbital period of the motion of the satellite around the Earth is $T_1 \approx 1{,}75\,h$.

0,75 **2.** The satellite S is placed at another circular orbit at an altitude h_2 of the surface of the Earth.

The motion of the satellite is circular uniform of the orbital period $T_2 = 24\,h$.

By using the Kepler's 3rd law, determine the altitude h_2 of this satellite.