وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات الرسميّة	امتحانات الشهادة الثانوية العامة الفرع: علوم الحياة	دورة العام ٢٠١٧ العاديّة الخميس ١٥ حزيران ٢٠١٧

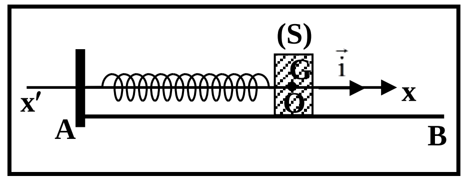
مسابقة في مادة الفيزياء المدة: ساعتان	الاسم: الرقم:

This exam is formed of three exercises in four pages.
The use of non-programmable calculator is recommended.

Exercise 1: (6 points) **Mechanical oscillator**

Consider a mechanical oscillator formed of a massless spring of stiffness k and a solid (S) of mass m = 0.4 kg.

The aim of this exercise is to determine the stiffness k of the spring by two different methods. For this aim, the spring is placed horizontally, fixed from one of its extremities to a fixed support and (S) is attached to the other extremity. (S) may slide without friction on a horizontal rail AB and its center of inertia G can move along a horizontal axis x'x.

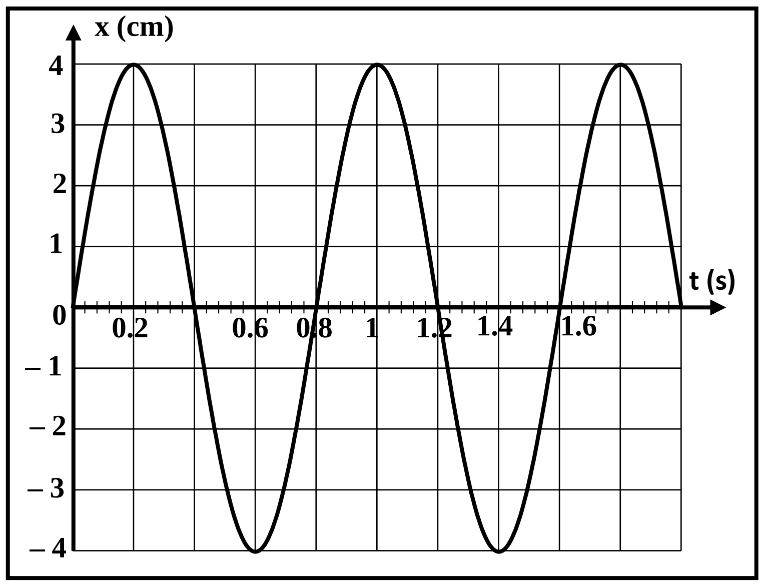


Doc. 1

At equilibrium, G coincides with the origin O of the axis x'x (Doc. 1).
At the instant $t_0 = 0$, G is at rest at O, (S) is launched with an initial velocity in the positive direction along x'x. Thus, (S) performs mechanical oscillations.

At an instant t, the abscissa of G is $x = \overline{OG}$ and the algebraic value of its velocity is $v = \frac{dx}{dt}$.

The horizontal plane passing through G is considered as the reference level for gravitational potential energy. Take $\pi^2 = 10$.



Doc. 2

1 – First method

A convenient apparatus is used to trace the curve of the abscissa x as a function of time (Doc. 2).

1-1) Referring to the graph of document 2, indicate:

1-1-1) the type of the oscillations of (S). Justify.

1-1-2) the value of the amplitude X_m of the oscillations;

1-1-3) the value of the proper period T_0 of the oscillations.

1-2) Indicate the nature of the motion of G and choose, from table below, the differential equation in x which describes the motion of G.

Equation 1	Equation 2	Equation 3
$x' + \frac{k}{m} x = 0$	$x'' + \frac{k}{m} x = 0$	$x'' + \frac{k}{m} x' = 0$

1-3) Determine the value of the stiffness k of the spring.

2 – Second method

2-1) The mechanical energy of the system [(S), spring, Earth] is conserved. Why?

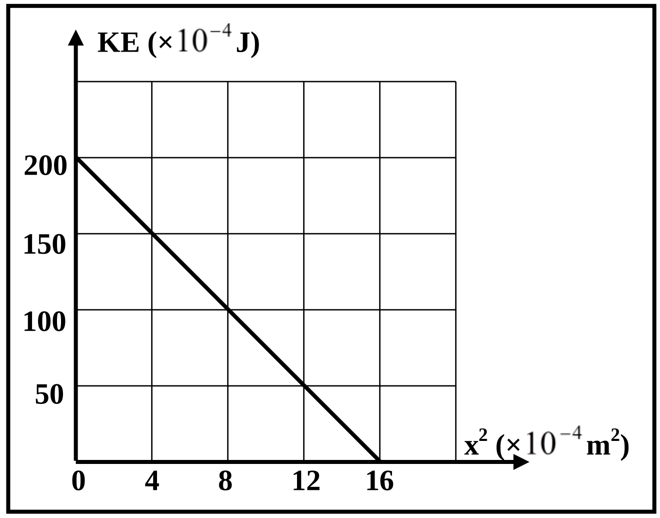
2-2) The expression of the kinetic energy of (S) can be written in the form: $KE = A - \frac{1}{2} k x^2$, where A is constant. What does A represent? Justify.

2-3) A convenient apparatus is used to trace the curve of the kinetic energy of (S) as a function of x^2 (Doc. 3). Using the graph of document 3, determine:

2-3-1) the value of A;

2-3-2) the value of the amplitude X_m of the oscillations;

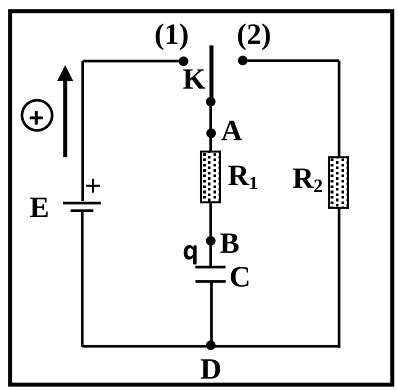
2-3-3) the value of the stiffness k.



Doc.3

<u>Exercise 2</u>: (7 points) **Charging and discharging of a capacitor**

The aim of this exercise is to determine the capacitance of a capacitor by two different methods.
Consider the circuit represented in document 1. It is formed of an ideal generator that maintains across its terminals a constant voltage of value E, a capacitor of capacitance C, two resistors of resistances $R_1 = 10\ k\Omega$, $R_2 = 20\ k\Omega$ and a double switch K.



Doc. 1

1 – Charging the capacitor

The capacitor is initially neutral. At the instant $t_0 = 0$, we put K in position (1); the charging phenomenon of the capacitor starts.

1-1) Theoretical study

1-1-1) Show that the differential equation that describes the variation of the voltage $u_C = u_{BD}$ across the capacitor has the form: $E = R_1 C \frac{du_C}{dt} + u_C$.

1-1-2) The solution of this differential equation has the form: $u_C = A(1 - e^{\frac{-t}{\tau_1}})$.
Determine the expressions of the constants A and τ_1 in terms of E, R_1 and C.

1-1-3) Deduce that $u_C = E$ at the end of charging of the capacitor.

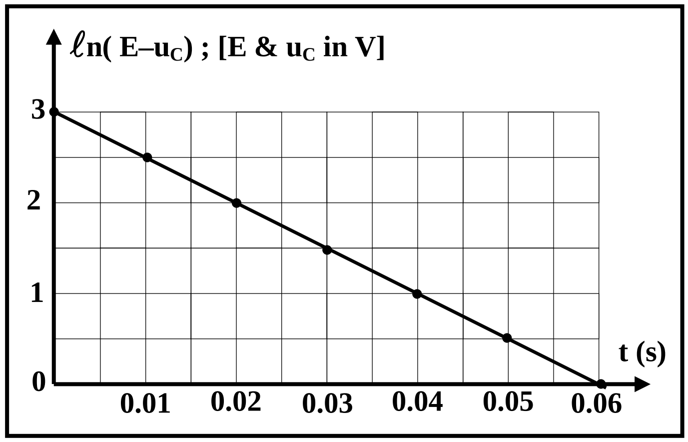
1-2) Experimental study

In order to determine the value of C, we use a convenient apparatus, which traces, during the charging of the capacitor, the curve representing $\ell n(E - u_C) = f(t)$ (Doc.2). [ℓn is the natural logarithm]

1-2-1) Determine, using the solution of the obtained differential equation, the expression of $\ell n\,(E - u_C)$ in terms of E, R_1, C and t.

1-2-2) Show that the shape of the curve in document 2 is in agreement with the obtained expression of $\ell n\,(E - u_C) = f(t)$.

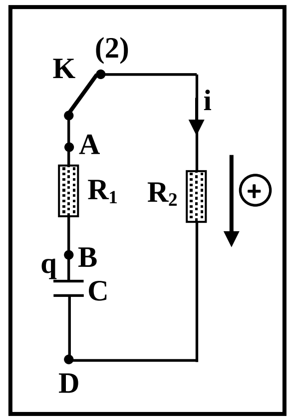
1-2-3) Using the curve of document 2, determine the values of E and C.



Doc. 2

2 – Discharging the capacitor

The capacitor being fully charged. At an instant taken as a new origin of time $t_0 = 0$, the switch K is placed at position (2); thus the phenomenon of discharging of the capacitor starts (Doc. 3).



Doc. 3

2-1) Theoretical study

2-1-1) Show that the differential equation in the voltage $u_C = u_{BD}$ across the capacitor has the form: $u_C + \alpha \frac{du_C}{dt} = 0$; where α is a constant to be determined in terms of R_1, R_2 and C.

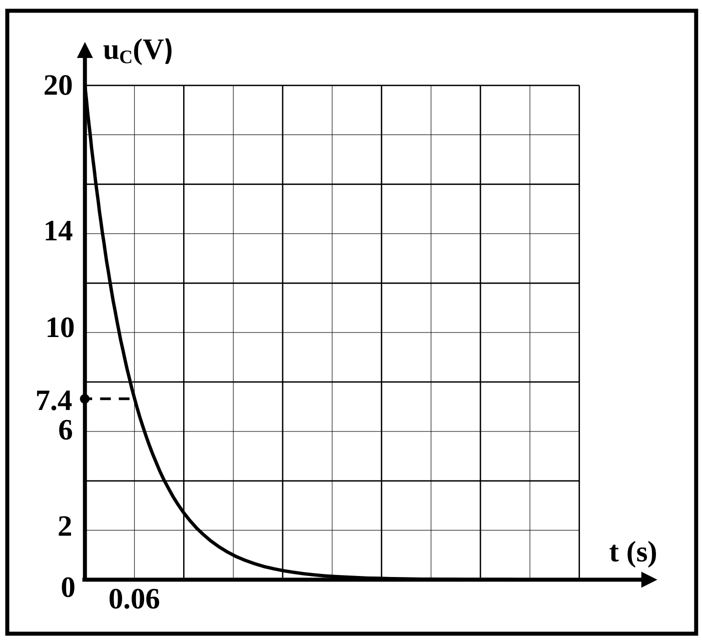
2-1-2) The solution of this differential equation has the form: $u_C = E\,e^{\frac{-t}{\tau_2}}$ where τ_2 is constant. Show that $\tau_2 = \alpha$.

2-2) Experimental study

The variation of the voltage u_C across the capacitor as a function of time is represented in document 4.

2-2-1) Determine, using document 4, the value of the time constant τ_2 of the discharging circuit.

2-2-2) Deduce the value of C.



Doc. 4

<u>Exercise 3</u> (7 points) **The radioactive isotope phosphorus 32**

The radioactive isotope phosphorus 32 ($^{32}_{15}P$) is used in the diagnosing of cancer. Phosphorus 32, is injected into the human body, it decays and gives radiations. These radiations are detected by an appropriate device to create the image of the inside of the human body.

The aim of this exercise is to determine the dose of radiation absorbed by a tissue of a patient during 6 days.

Phosphorus 32 ($^{32}_{15}P$) is a β^- emitter; it disintegrates to give an isotope $^{A}_{Z}S$ of sulfur.

Given:

- mass of $^{32}_{15}P$: 31.965 678 u;
- mass of $^{A}_{Z}S$: 31.963 293 u;
- mass of electron : 5.486×10^{-4} u ;
- The radioactive period of $^{32}_{15}P$: 14.3 days;
- 1 u = 931.5 MeV/c² ;
- 1 MeV = 1.6×10^{-13}J.

1 – Energy liberated by the decay of phosphorus 32

The disintegration of phosphorus 32 nucleus is given by the following reaction:

$$^{32}_{15}P \rightarrow {}^{A}_{Z}S + {}^{0}_{-1}e + {}^{0}_{0}\bar{\upsilon}$$

1-1) Determine A and Z.

1-2) Prove that the energy liberated by the above disintegration is E_{lib} = 1.7106 MeV.

1-3) The sulfur nucleus is produced in the ground state. The emitted antineutrino carries energy of 1.011 MeV.

1-3-1) The above disintegration of phosphorus 32 is not accompanied with the emission of gamma rays. Why?

1-3-2) Calculate the kinetic energy carried by the emitted electron knowing that phosphorus and sulfur are considered at rest.

2 – Absorbed dose

A patient is injected by a pharmaceutical product containing phosphorus 32. The initial activity of phosphorus 32 in the pharmaceutical product at $t_0 = 0$, is $A_0 = 1.36\times10^6$ Bq.

2-1) Calculate, in s^{-1}, the radioactive constant of phosphorus 32.

2-2) Deduce the number N_o of nuclei of phosphorus 32 present in the pharmaceutical product at $t_0 = 0$.

2-3)

2-3-1) Determine the remaining number N of nuclei of phosphorus 32 at t = 6 days.

2-3-2) Deduce the disintegrated number N_d of nuclei of phosphorus 32 during the 6 days.

2-3-3) The number of the emitted electrons is $N_{e^-} = 6.12\times10^{11}$ electrons during the 6 days. Why?

2-4) The emitted radiation is absorbed by a tissue of mass M = 112 g. The antineutrino does not interact with matter, and suppose that the energy of the emitted electrons is completely absorbed by the tissue.

2-4-1) Calculate the energy E_{abs} absorbed by the tissue during the 6 days.

2-4-2) The absorbed dose by the tissue is $D = \frac{E_{abs}}{M}$ during the 6 days. Deduce the value of D in J/kg.

دورة العام ٢٠١٧ العادية الخميس ١٥ حزيران ٢٠١٧	امتحانات الشهادة الثانوية العامة الفرع: علوم الحياة	وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات
أسس التصحيح	مسابقة في مادة الفيزياء المدة: ساعتان	

Exercise 1: (6 points) **Mechanical oscillator**

Part			Solution	Mark
1	1-1	1-1-1	Free un-damped oscillation Since the amplitude is constant	0.25 0.25
		1-1-2	X_m = 4 cm.	0.5
		1-1-3	T_0 = 0.8 s.	0.5
	1-2		Nature simple harmonic motion or RSM Equation 2.	0.25 0.25
	1-3		The differential equation has the form : $x'' + \omega_0^2 x = 0$ $\omega_0 = \sqrt{\frac{K}{m}} = \frac{2\pi}{T_0}$; $\omega_0 = \frac{2\pi}{T_0} = 2.5\,\pi\ \mathrm{rad/s}$; $\omega_0 = \sqrt{\frac{K}{m}}$; $K = m \times \omega_0^2 = 25$ N/m	0.5 0.5
2	2-1		The mechanical energy of (S) is conserved due to the absence of friction **Or** : X_m = constant **Or:** The work done by the non conservative forces is zero.	0.25
	2-2		ME= KE + PE_e ; KE= ME - ½k $(x)^2$; A is mechanical energy	0.5 0.25
	2-3	2-3-1	For x = 0 ; KE = ME = A = 0.02 J	0.5
		2-3-2	KE = 0 ; x = X_m, from the graph X_m^2 = 16 cm^2 , then X_m = 4 cm	0.75
		2-3-3	Slope = $\frac{KE_f - KE_i}{x_f^2 - x_i^2} = \frac{-200}{16} = -12.5\ J/m^2$; -12.5 = - ½ k , then k = 25 N/m **Or** : choose a point on the graph for x = X_m ; KE = 0J $X_m^2 = \frac{2A}{K}$, therefore k = 25 N/m	0.75

<u>Exercise 2</u>: (7 points) **Charging and discharging of a capacitor**

Partie			Solution	Note
1	1.1	**1-1-1**	$u_{AD} = u_{AB} + u_{BD}$, then $E = R_1 i + u_C$ with $i = C\frac{du_C}{dt}$ we get : $E = R_1 C\frac{du_C}{dt} + u_C$	**0.5**
		1-1-2	$\frac{du_C}{dt} = \frac{A}{\tau_1} e^{\frac{-t}{\tau_1}}$, replacing in the differential equation we get: $E = R_1 C\frac{A}{\tau_1} e^{\frac{-t}{\tau_1}} + A(1 - e^{\frac{-t}{\tau_1}})$, then A = E and $\tau_1 = R_1 C$	**0.25** **0.5** **0.5**
		1-1-3	At the end of charging, $t \to \infty$, then $e^{\frac{-t}{\tau_1}} \to 0$, thus $u_C = E$ **<u>Or</u>** for t = 5τ ; uc = 0.99 E = E	**0.5**
	1-2	**1-2-1**	$u_C = E(1 - e^{\frac{-t}{\tau_1}})$; $uc = E - E e^{\frac{-t}{\tau_1}}$; $E - u_c = E\ e^{\frac{-t}{\tau_1}}$; $\ell n\ (E - u_C) = \ell n\ (E\ e^{\frac{-t}{\tau_1}})$ $\ell n\ (E - u_C) = \ell n\ E - \frac{t}{R_1 C}$	**0.5**
		1-2-2	$\ell n\ (E - u_C)$ has the form of y = at + b its slope a < 0 ; Is in agreement with the shape of the curve which is a straight line of negative slope not passing through the origin.	**0.5**
		1-2-3	The slope of this straight line is $-\frac{1}{R_1 C} = \frac{2.5 - 3}{0.01} = -50$, then $\frac{1}{R_1 C} = 50$ $C = 2\times10^{-6}$ F = 2 μF and ℓn E = 3 , thus E = 20 V **<u>Or</u>** : For t = 0 , then $\ell n\ (E - u_C) = 3$; 3 = ℓn E , thus E = 20 V For $\ell n\ (E - u_C) = 0$, so t = 0.06 s , thertefore $C = 2\times10^{-6}$ F	**0.5** **0.5**
2	2.1	**2-1-1**	$u_C = (R_1 + R_2)\ i$ with $i = -C\frac{du_C}{dt}$, we get : $u_C + (R_1 + R_2)\ C\frac{du_C}{dt} = 0$. $u_C + \alpha\frac{du_C}{dt} = 0$, then $\alpha = (R_1 + R_2)\ C$.	**1**
		2-1-2	Replacing u_C by $u_C = E\ e^{\frac{-t}{\tau_2}}$ in the differential equation we get: $E\ e^{\frac{-t}{\tau_2}} + \alpha\ (-\frac{E}{\tau_2}\ e^{\frac{-t}{\tau_2}}) = 0$, therefore $\alpha = \tau_2$	**0.25** **0.5**
	2.2	**2.2-1**	For uc = 7.4 V , then t = 0.06 s ; $7.4 = 20\ e^{\frac{-0,06}{\tau_2}}$, thus $\tau_2 = 0.0603$ s Or: From the graph at t = 0.06 s, $u_C = 7.4 = 0.37 \times 20$, so $\tau_2 = 0.06$ s.	**0.5**
		2.2-2	$\tau_2 = (R_1 + R_2)\ C$, then $C = 2\times10^{-6}$F = 2 μF	**0.5**

Exercise 3: (7 points) **The radioactive isotope phosphore 32**

Part			Solution	Mark
1	1-1		${}^{32}_{15}P \rightarrow {}^{A}_{Z}S + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$. By applying Soddy's laws: 32= A + 0 + 0 , Then A = 32; 15 = Z – 1 + 0 , then Z = 16.	0.25 0.5
	1-2		$\Delta m = m_{before} - m_{after}$ = 31.965678 – (31.963293 + 5.486 $\times 10^{-4}$) = 1.8364×10^{-3} u $\Delta m = 1.8364 \times 10^{-3} \times 931.5\ MeV/c^2 \cong 1.706\ MeV/c^2$. $E_{lib} = \Delta m \cdot c^2 = 1.711 \frac{Mev}{c^2} \cdot c^2$, then $E_{lib} = 1.706$ MeV	0.5 0.75
	1-3	1-3-1	Gamma rays are not emitted in the above decay since the daughter nucleus (sulfur) is produced in the ground state.	0.25
		1-3-2	$E_{lib} = KE_{\beta^-} + E_{\nu^-}$, so $1.7106 = KE_{\beta^-} + 1.011$, therefore $KE_{\beta^-} = 0.6996$ MeV.	0.5
2	2-1		$\lambda = \frac{\ell n\ 2}{T} = \frac{\ell n\ 2}{14.3 \times 24 \times 3600}$, therefore $\lambda = 5.61 \times 10^{-7} s^{-1}$	0.75
	2-2		$A_o = \lambda N_o$, $N_o = \frac{1.36 \times 10^6}{5.61 \times 10^{-7}}$, therefore $N_o = 2.424 \times 10^{12}$ nuclei	0.75
	2-3	2-3-1	$n = \frac{t}{T} = \frac{6}{14.3} = 0.4195$, $N = \frac{N_o}{2^n} = \frac{2.424 \times 10^{12}}{2^{0.4195}}$, therefore $N = 1.812 \times 10^{12}$ nuclei	1
		2-3-2	$N_d = N_o - N = 2.424 \times 10^{12} - 1.812 \times 10^{12}$, therefore $N_d = 6.12 \times 10^{11}$ nuclei	0.5
		2-3-3	One electron is emitted in one decay of phosphorous-32, so $N_{e^-} = N_{decay}$ Therefore, $N_{e^-} = 6.12 \times 10^{11}$	0.25
	2-4	2-4-1	$E_{absorb} = N_{decay} \times KE_{\beta^-} = 6.12 \times 10^{11} \times 0.6996 \times 1.6 \times 10^{-13}$ J So $E_{absorb} = 6.8504 \times 10^{-2}$ J	0.5
		2-4-2	$D = \frac{E_{absorb}}{m} = \frac{6.8504 \times 10^{-2}}{0.112}$, therefore D = 0.611 Gy = 0.611 J/kg.	0.5