وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات الرسميّة	امتحانات الشهادة الثانوية العامة الفرع: علوم الحياة	دورة العام ٢٠١٨ الاستثنائيّة السبت في ٤ آب ٢٠١٨
	مسابقة في مادة الفيزياء المدة: ساعتان	الاسم: الرقم:

This exam is formed of three obligatory exercises in 3 pages.

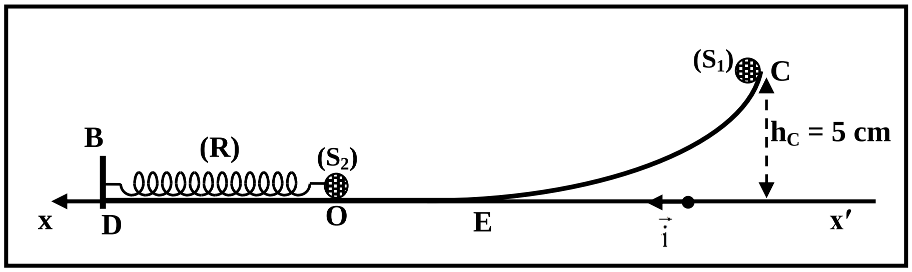
The use of non-programmable calculator is recommended

Exercise 1 (7 points)

Determination of the stiffness of a spring

In order to determine the stiffness k of a spring (R), we consider:

- a track CEOD, situated in a vertical plane, formed of a curved part CE and a horizontal part EOD ;
- a horizontal spring (R) of negligible mass and stiffness k;
- two identical objects (S_1) and (S_2) considered as particles and of same mass m.



Doc .1

We fix the spring (R) from one of its ends to a support B; whereas the other end is connected to the object (S_2).

At equilibrium, (S_2) coincides with the origin O of a horizontal x-axis of unit vector $\vec{i}$.

We release (S_1) without initial speed from point C situated at a height h_C = 5 cm above the x-axis as shown in document 1.

Neglect all the forces of friction.

Take:

- the horizontal plane containing the x-axis as a reference level for gravitational potential energy;
- $g = 10\ m/s^2$ and $\pi = 3.14$.

1. (S_1) reaches (S_2) with a velocity $\overrightarrow{V_1} = V_1\ \vec{i}$. Apply the principle of conservation of mechanical energy of the system [(S_1) – Earth] to determine the magnitude V_1 of $\overrightarrow{V_1}$.

2. (S_1) enters into a head on elastic collision with (S_2) which is initially at rest. Verify that, just after this collision, (S_1) becomes at rest and (S_2) moves with a speed V_0 = 1 m/s.

3. Just after the collision, (S_2) oscillates along the x-axis. The instant of the collision at point O is taken as an initial time $t_0 = 0$.

At an instant t, the abscissa of (S_2) is x and the algebraic value of its velocity is $v = \frac{dx}{dt}$.

3.1) Establish the second order differential equation in x that describes the motion of (S_2).

3.2) The solution of the obtained differential equation is $x = A \sin (\frac{2\pi}{T_0} t)$, where A is constant and T_0 is the proper period of the oscillation of (S_2).

3.2.1) Determine the expression of T_0 in terms of m and k.

3.2.2) Determine the expression of A in terms of V_0 and T_0.

3.2.3) The constant A is a characteristic of the oscillatory motion of (S_2). Name this characteristic.

4. At an instant t_1 = 314 ms, (S_2) returns back to point O for the first time. Deduce the value of T_0.

5. Calculate the value of A.

6. Determine by two different methods the value of k, knowing that m = 400 g.

Exercise 2 (7 points)

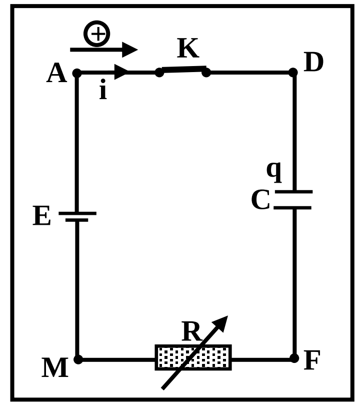
Effect of the resistance on the charging of a capacitor

The aim of this exercise is to study the effect of the resistance of a resistor on the charging of a capacitor.

For this aim, we set-up the circuit of document 2 that includes:

- a capacitor, initially uncharged, of capacitance $C = 4\ \mu F$;
- a resistor of adjustable resistance R;
- an ideal battery of voltage $u_{AM} = E$;
- a switch K.

We close the switch at $t_0 = 0$, and the charging process starts.



Doc. 2

1. Theoretical study

1.1) Derive the differential equation that describes the variation of the voltage $u_{DF} = u_C$ during the charging of the capacitor.

1.2) The solution of this differential equation has the form of: $u_C = A + B\,e^{Dt}$. Determine the constants A, B and D in terms of E, R and C.

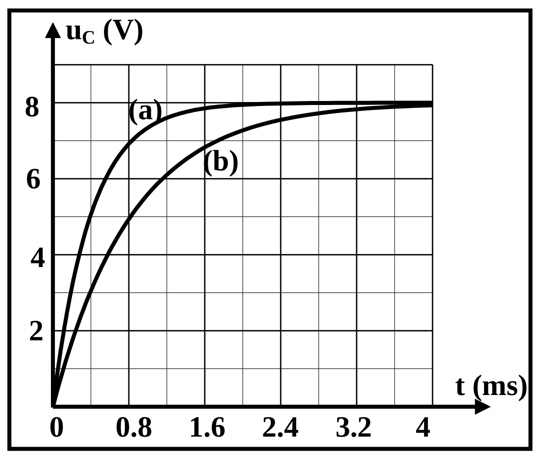
1.3) Verify that the capacitor becomes practically fully charged at t = 5 RC.

1.4) Indicate the effect of the resistance of the resistor on the duration of the charging of the capacitor.

2. Experimental study

We adjust R to two different values R_1 and R_2; an appropriate device allows to trace, for each value of R, the voltage u_C as a function of time (Doc. 3).

- curve (a) corresponds to $R = R_1$.
- curve (b) corresponds to $R = R_2$.



Doc. 3

2.1) Using the curves of document 3:

2.1.1) specify the value of E;

2.1.2) specify, without calculation, whether the value of R_2 is: equal to, greater than, or less than the value of R_1;

2.1.3) determine the values of R_1 and R_2.

2.2) The capacitor is fully charged, the electric energy stored in the capacitor is W_C.

2.2.1) Is the value of W_C affected by the resistance of the resistor? Justify.

2.2.2) Deduce the value of W_C.

<u>Exercise 3</u> (6 points)

The nuclear bomb of Hiroshima

On August 6, 1945, an atomic (nuclear) bomb, fueled by highly enriched uranium (uranium-235), dropped on Hiroshima. It caused a violent explosion due to the chain nuclear fission of that uranium.

The bomb contained M = 52 kg of uranium-235, only a small part of mass "m" of these nuclei was fissioned before the explosion ejected the material of the bomb away.

The aim of this exercise is to study nuclear fission and to determine the percentage of uranium-235 that was fissioned in that bomb.

1. Studying of the nuclear fission reaction

When the fissionable nucleus uranium-235 is bombarded by a thermal neutron ${}_{0}^{1}n$, it splits into two lighter nuclei with the emission of some neutrons.

One of the possible reactions is:

$${}_{0}^{1}n + {}_{92}^{235}U \rightarrow {}_{53}^{A}I + {}_{B}^{94}Y + 3\,{}_{0}^{1}n$$

Given: $m_n = 1.00866$ u;

$m({}_{92}^{235}U) = 234.99332$ u;

$m({}_{53}^{A}I) = 138.89700$ u;

$m({}_{B}^{94}Y) = 93.89014$ u;

$1\ u = 1.66 \times 10^{-27}$ kg;

$c = 3 \times 10^{8}$ m/s.

1.1) This reaction leads to a nuclear chain reaction. Why?

1.2) Calculate, indicating the used laws, the values of A and B.

1.3) Determine the mass defect Δm, which is converted into energy, in the above fission nuclear reaction.

1.4) Deduce that, 0.08 % of the mass of one uranium-235 nucleus that undergoes this fission is converted into energy.

2. Determination of the percentage of uranium-235 used in the bomb of Hiroshima

In nuclear bomb, the nuclear reactions are uncontrolled. The large amount of the released energy creates a nuclear explosion. The bomb dropped on Hiroshima released an amount of energy equivalent to the energy liberated by 14 kilotons of TNT.

2.1) Calculate the total nuclear energy liberated by the atomic bomb, knowing that each 1 kiloton of TNT liberates energy of 4×10^{12} J.

2.2) Deduce that the mass of uranium-235 nuclei, converted into energy during the explosion of the bomb, is Δm' = 622.22 mg.

2.3) The mass of uranium-235 that undergoes fission in the bomb is "m". Assume that, 0.08% of "m" is converted into energy. Calculate "m".

2.4) Out of M = 52 kg of uranium-235, calculate the percentage of the mass of uranium-235 that was fissioned in the bomb of Hiroshima.

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الفرع: علوم الحياة
مسابقة في مادة الفيزياء

دورة العام ٢٠١٨ الاستثنائيّة
السبت في ٤ آب ٢٠١٨

أسس التصحيح

Exercise 1 (7 points)

Determination of the stiffness of a spring

Part			Answer	Mark
1			$ME_A = ME_O$, then $m\,g\,h_G + 0 = ½\, mV_1^2 + 0$, so $V_1 = \sqrt{2\,g\,h_G} = \sqrt{2 \times 10 \times 0.05} = 1$ m/s	0.75
2			During collision, the linear momentum of the system (S_1, S_2) must be conserved: $\vec{P}_{\text{juste before}} = m\,\vec{V}_1 + \vec{0} = m \times 1\vec{\imath}$ $\vec{P}_{\text{juste after}} = \vec{0} + m\,\vec{V}_o = m \times 1\,\vec{\imath}$ $\vec{P}_{\text{juste before}} = \vec{P}_{\text{juste after}}$ It's verified **Or** : During collision, the linear momentum of the system (S_1, S_2) is conserved: $m\,\vec{V}_1 + \vec{0} = \vec{0} + m\,\vec{V}_o$ therefore $\vec{V}_o = \vec{V}_1$ Then $V_o = 1$ m/s it's verified. **Or** : conservation of kinetic energy	0.75
3	3.1		$ME = \frac{1}{2}\,m\,v^2 + \frac{1}{2}\,k\,x^2$ The sum of the work done by the non-conservative forces is zero, so ME is conserved: $\frac{dEm}{dt} = 0 = 2\,(\frac{1}{2}\,m\,vv') + 2\,(\frac{1}{2}\,k\,xx')$, but $x' = v$ and $v' = x''$, then $v\,(m\,x'' + k\,x) = 0$, but $v = 0$ is rejected, so $m\,x'' + k\,x = 0$, therefore $x'' + \frac{k}{m}\,x = 0$	1
3	3.2	1	$x' = \frac{A\,2\pi}{T_o}\cos\left(\frac{2\pi}{T_o}t\right)$, $x'' = -A\left(\frac{2\pi}{T_o}\right)^2\sin\left(\frac{2\pi}{T_o}t\right) = -\left(\frac{2\pi}{T_o}\right)^2 x$. Substitute in the differential equation, then $-\left(\frac{2\pi}{T_o}\right)^2 x + \frac{k}{m}\,x = 0$ $x\left[-\left(\frac{2\pi}{T_o}\right)^2 + \frac{k}{m}\right] = 0$, but $x = 0$ is rejected , so $T_o = 2\pi\sqrt{\frac{m}{k}}$	1
3	3.2	2	$V = x' = \frac{2\pi}{T_o}\,A\cos\left(\frac{2\pi}{T_o}t\right)$ At $t_o = 0$, $v' = V_o = \frac{A\,2\pi}{T_o}\cos(0)$, then $A = \frac{T_o V_o}{2\pi}$	1
3	3.2	3	A is the amplitude of the oscillation of (S_2)	0.25
4			$T_o = 2\,t_1 = 2 \times 0.314 = 0.628$ s	0.5
5			$A = \frac{0.628 \times 1}{2 \times 3.14} = 0.1$ m	0.5
6			First method: $T_o = 2\pi\sqrt{\frac{m}{k}}$, then $k = \frac{4\pi^2 \times m}{T_o^2} = \frac{4 \times 3.14^2 \times 0.4}{0.628^2} = 40$ N/m. Second method: system [(S_2), (R), Earth] $½\, m\,V_o^2 + 0 = ½\, k\,A^2 + 0$, so $k = \frac{m\,V_o^2}{A^2} = \frac{0.4 \times 1^2}{0.1^2} = 40$ N/m.	0.5 0.75

Exercise 2 **(7 points)**

Effect of resistance on the charging process of a capacitor

Part			Answer	Mark
1	1.1		$u_{AM} = u_{AD} + u_{DF} + u_{FM}$, so $E = u_C + R\,i$ The positive sense is directed towards the plate of charge q, so $i = +\frac{d\,q}{d\,t}$, then $i = C\,\frac{d\,u_C}{d\,t}$. $E = u_C + R\,C\frac{d\,u_C}{d\,t}$, therefore $\frac{d\,u_C}{d\,t} + \frac{u_C}{RC} = \frac{E}{RC}$.	**0.75**
	1.2		$u_C = A + B\,e^{D\,t}$, so $\frac{d\,u_C}{d\,t} = BD\,e^{Dt}$, substitute in the differential equation $BD\,e^{Dt} + \frac{A + B\,e^{D\,t}}{R\,C} = \frac{E}{R\,C}$, then $RC\,B\,D\,e^{Dt} + A + Be^{Dt} = E$ $Be^{Dt}\,(RC\,D + 1) + A = E$. $A = E$; and $Be^{Dt}\,(RC\,D + 1) = 0$. But $Be^{Dt} = 0$ is rejected, then $(R\,C\,D + 1) = 0$, thus $D = -\frac{1}{R\,C}$. At $t_o = 0$, $u_C = 0 = A + B\,e^{D\,t}$, so $0 = A + B$, then $B = -A$, therefore $B = -E$.	**1.25**
	1.3		$u_C = E\,(1 - e^{\frac{-t}{R\,C}})$ At t = 5 RC: $u_C = E\,(1 - e^{\frac{-5\,RC}{R\,C}}) = E\,(1 - e^{-5})$, then $u_C = 0.99$ E. Therefore, the capacitor becomes practically fully charged at t = 5 R C.	**0.75**
	1.4		With higher resistance, the charging time (5 R C) increases, therefore the charging process becomes slower.	**0.5**
2	2.1	1	When the steady state is attained, the capacitor becomes fully charged, then $u_C = E$. Graphically, steady state is attained when $u_C = 8$ V. Therefore E = 8 V.	**0.75**
		2	On the graph, $u_{C_{(b)}} < u_{C_{(a)}}$ at any instant (except for 0), so the charging process in curve (b) is slower, thus $R_2 > R_1$.	**0.75**
		3	At $t = \tau$, $u_C = 0.63\,E = 0.63 \times 8 = 5$ V. Graphically, $u_C = 5$ V ,when : $t = \tau_1 = 0{,}4$ ms for curve (a) and $t = \tau_2 = 0{,}8$ ms for courbe (b). $\tau = R_1C$, donc $R_1 = \frac{0.4 \times 10^{-3}}{4 \times 10^{-6}}$; $R_1 = 100\ \Omega$ similarly $R_2 = 200\ \Omega$	**1,25**
	2.2	2.	$W_C = \frac{1}{2}C\,E^2$, then W_C depends only on C and E. Therefore the value of W_C is not affected by the value the resistance of the circuit.	**0.5**
		2.	$W_C = \frac{1}{2}C\,E^2 = \frac{1}{2}(4 \times 10^{-6})\,(8^2)$, therefore $W_C = 1.28 \times 10^{-4}$ J.	**0.5**

<u>Exercise 3</u> (6 points)

The nuclear bomb of Hiroshima

Part		Answer	Mark
1	1.1	Since each nuclear reaction liberates 3 neutrons.	**0.5**
	1.2	Law of conservation of mass number: 1+ 235 = A + 94 + 3(1) then A = 139 Law of conservation of charge number: 0+ 92 = 53 + B + 3(0) then B = 39	**1**
	1.3	$\Delta m = m_{before} - m_{after}$ = (1.00866 + 234.99332)- [138.897+ 93.89014 + 3(1.00866)] Δm = 0.18904 u.	**0.75**
	1.4	$\frac{\Delta m}{m(U)} = \frac{0.18904}{234.99332} = 0.0008 = 0.08\ \%$	**0.75**
2	2.1	$E_{\text{total liberated by the atomic bomb}} = 14 \times 4 \times 10^{12} = 56 \times 10^{12}$ J	**0.5**
	2.2	$E_{\text{total liberated by the atomic bomb}} = \Delta m' \times c^2$ Then $\Delta m' = \frac{56\times10^{12}}{(3\times10^{8})^2} = 0.00062222\text{kg} = 0.62222\text{g} = 622.22\text{mg}.$	**1**
	2.3	0,08% m = $\Delta m'$ then : $m = \frac{\Delta m'}{0.08\%} = \frac{0.62222}{0.0008} = 777.775\text{ g} = 0.777\text{ kg}.$	**0.75**
	2.4	Ratio = $\frac{m}{M} = \frac{0.777}{52} = 0.015 = 1.5\%.$ Pourcentage = $\frac{m}{M}\times100 = \frac{0.777}{52}\times100 = 1.5$	**0.75**