الدورة العادية للعام 2010	امتحانات الشهادة الثانوية العامة الفرع : علوم عامة	وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات
الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ثلاث ساعات	

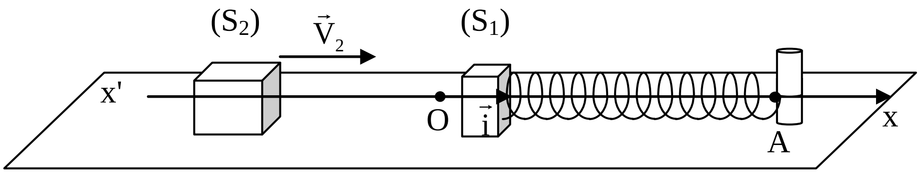
This exam is formed of four exercises in four pages numbered from 1 to 4

The use of non-programmable calculator is recommended

First Exercise *(7.5 points)* *Mechanical oscillator*

Two solids (S_1) and (S_2), of respective masses $m_1 = 100$ g and $m_2 = 500$ g, can slide on a horizontal table. The solid (S_1) is fixed to one end of a spring with un-jointed turns and of negligible mass and of stiffness k = 25 N/m, the other end A of the spring being fixed to a support as shown in the figure below. (S_2) is launched towards (S_1) and attains, just before impact, the velocity $\vec{V}_2 = V_2\ \vec{i}$ where $V_2 = 0.48$ m/s. Due to collision, (S_2) sticks to (S_1) thus forming a single solid (S), just after collision, at the instant $t_0 = 0$, whose center of inertia G moves with the velocity $\vec{V}_0 = V_0\,\vec{i}$.

The horizontal plane through G is taken as a gravitational potential energy reference.



A- Theoretical Study

Neglect all forces of friction.

1) Show that $V_0 = 0.40$ m/s

2) After collision, (S), still connected to the spring, continues its motion. At an instant t, we define the position of G by its abscissa x on the axis (O, $\vec{i}$), $v = \frac{dx}{dt}$ being the algebraic measure of the velocity of G. The origin O of abscissas is the position of G at the instant $t_0 = 0$.

a) Calculate the mechanical energy of the system [(S), spring, Earth] at the instant $t_0 = 0$.

b) Give, at the instant t, the expression of the mechanical energy of the system [(S), spring, Earth] in terms of m_1 , m_2, k, x and v.

c) Deduce that the abscissa of G is 6.2 cm when v is equal to zero for the first time.

3) a) Derive the second order differential equation of the motion of G.

b) The solution of this differential equation is of the form: $x = X_m \sin(\omega_0 t + \varphi)$.

i) Determine the values of the constants X_m , ω_0 and φ.

ii) Calculate the value of the proper period T_0 of oscillations of G and deduce the time t_1 needed by G to pass from O to the position where v becomes zero for the first time.

B- Experimental study

In fact, (S), again shot with the velocity $\vec{V}_0$ at the instant $t_0 = 0$, performs oscillations of pseudo-period very close to T_0. The velocity of G becomes zero for the first time at the instant t_1 but the abscissa of G is just 6cm.

1) Determine the energy lost during t_1.

2) An apparatus (D), conveniently connected to the oscillator, provides energy in order to compensate for the loss. Calculate the average power provided by (D).

3) The oscillator is at rest. The apparatus (D) and the support are removed. The end A of the spring is connected to a vibrator, which vibrates along the spring, with an adjustable frequency f.

a) In steady state, (S) performs oscillations of frequency f. Why?

b) For a certain value f_1 of f, the amplitude of oscillations of (S) attains a maximum value.

i) Give the name of the phenomenon that thus took place.

ii) Calculate the value of f_1.

Second Exercise *(7.5 points)* *Duration of charging and discharging of a capacitor*

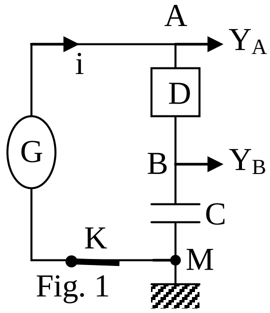


Fig. 1

Consider the circuit whose diagram is shown in figure 1, where G is a generator delivering a square signal (E, 0) of period T (Fig. 2), D a resistor of resistance R = 10 kΩ and (C) a capacitor of capacitance C = 0.2 μF. An oscilloscope displays the voltage $u_g = u_{AM}$ across G and the voltage $u_C = u_{BM}$ across (C).

A- Theoretical study

Charging of (C)

During the charging of (C), the voltage u_g has the value E and at an instant t , the circuit carries a current i.

1) Give the expression of i in terms C and $\frac{du_C}{dt}$.

2) Derive, for $0 \le t \le \frac{T}{2}$, the differential equation in u_C.

3) The solution of this differential equation has the form:

$u_C = A(1 - e^{-\frac{t}{\tau}})$, where A and τ are constants.

a) Determine, in terms of E, R and C, the expressions of A and τ.

b) Draw the shape of the graph representing the variation of u_C as a function of time and show, on this graph, the points corresponding to A and τ.

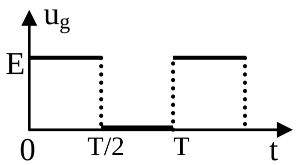


Fig.2

Discharging of (C)

4) During discharging of (C) the voltage u_g = 0. We consider the instant $\frac{T}{2}$ as a new origin of time.

Verify that $u_C = E\,e^{-\frac{t}{\tau}}$.

5) a) What must the minimum duration of charging be so that u_C reaches practically the value E?

b) What is then the minimum value of T?

B- Experimental study

1) On the screen of the oscilloscope, we observe the waveforms of figure 3.

a) Which curve corresponds to the charging of the capacitor? Justify the answer.

b) Calculate the value of E and that of the period T of the square signal.

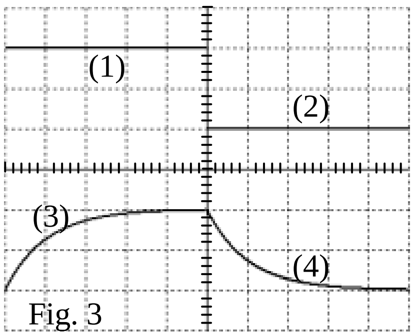


Fig. 3

S_V = 5 V/div; S_h = 2 ms/div.

2) a) We increase the frequency of the voltage delivered by G. The waveforms obtained are as in figure 4.

Determine the new period of the square signal.

Justify the shape of the waveform of u_C displayed.

b) We keep increasing the frequency of the voltage delivered by G. The waveform becomes almost triangular. Why?

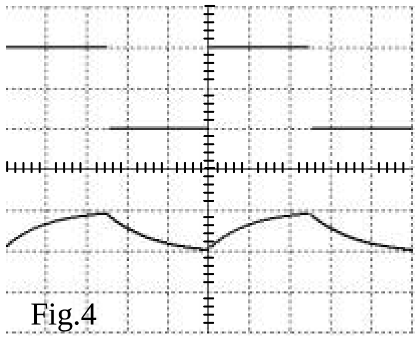


Fig.4

S_V = 5 V/div; S_h = 1 ms/div.

Third Exercise ***(7.5 points)*** ***Energy levels of the hydrogen atom***

The energy levels of the hydrogen atom are given by the relation:

$E_n = -\frac{13.6}{n^2}$; where E_n is expressed in eV and n is a non-zero whole number.

***Given*:** Planck's constant: $h = 6.62\times10^{-34}$ J.s; 1 eV = 1.6×10^{-19} J ; 1nm = 10^{-9} m

visible spectrum in vacuum: 400 nm $\leq \lambda \leq$ 750 nm; speed of light in vacuum $c = 3\times10^8$ m/s.

The Lyman series represents the set of radiations emitted by the hydrogen atom when it undergoes a downward transition from the level $n \geq 2$ to the ground state n = 1.

1) a) The energy of the hydrogen atom is said to be quantized.
What is meant by the term "quantized energy".

b) Write down the expression of the energy of a photon associated with a radiation of wavelength λ in vacuum.

2) a) Show that the wavelengths λ in vacuum of the radiations of the Lyman series are expressed in nm by the relation: $\lambda = 91.3\left(\frac{n^2}{n^2-1}\right)$.

b) i) Determine, in nm, the maximum wavelength λ_1 of the radiation of the Lyman series .

ii) Determine, in nm, the minimum wavelength λ_2 of the radiation of the Lyman series.

iii) Do the radiations of the Lyman series belong to the visible, ultraviolet or infrared spectrum? Justify your answer.

3) A hydrogen lamp illuminates a metallic surface of zinc whose threshold wavelength is λ_0 = 270 nm.

a) Define the threshold wavelength of a metal.

b) Electrons are emitted by the metallic surface of zinc. Why?

c) The maximum kinetic energy KE of an electron emitted by a radiation of the Lyman series is included between the values a and b: a $\leq$ KE $\leq$ b. Determine, in eV, the values of a and b.

d) The maximum kinetic energy of these emitted electrons is quantized. Why?

Fourth Exercise *(7.5 points) A nuclear reactor "The breeder reactor"*

Read carefully the following selection:

"*…..The nuclear reactors with fast neutrons use uranium 238 or plutonium 239 (or both at the same time) as fuels …….The principle of a breeder reactor is to produce, starting from uranium 238 an amount of fissionable material that is equal or exceeds what the reactor consumes since the final result would be the consumption of uranium 238 only which is more abundant than the uranium 235…..*"

Given :

Speed of light in vacuum: $c = 3 \times 10^8$ m/s. Mass of neutron (${}_0^1n$): 1.0087 u.

1 u = 931.5 MeV/c^2 = 1.66×10^{-27} kg ; 1 MeV = 1.6×10^{-13} J.

Element	***Tellurium***	***Technetium***	***Molybdenum***	***Plutonium***	***Neptunium***
Nuclide	${}_{52}^{135}Te$	${}_{43}^{102}Tc$	${}_{42}^{102}Mo$	${}_{94}^{239}Pu$	${}_{93}^{239}Np$
Mass (u)	***134.9167***	***101.9092***	***101.9103***	***239.0530***	***239.0533***

1) Draw from the selection an indicator showing that producing an equal amount of energy in a nuclear power plant, uranium 238 has an advantage over uranium 235.

2) In a breeder reactor, uranium 238 reacts with a fast neutron according to the following reaction:

$${}_{92}^{238}U + {}_0^1n \rightarrow {}_Z^AX. \quad (1).$$

The nucleus ${}_Z^AX$ obtained is radioactive; it is transformed into fissionable plutonium according to the following equations

$${}_Z^AX \rightarrow {}_{-1}^0e + {}_{Z_1}^{A_1}X_1 + {}_0^0\overline{\nu}. \quad (2)$$

$${}_{Z_1}^{A_1}X_1 \rightarrow {}_{-1}^0e + {}_{94}^{239}Pu + {}_0^0\overline{\nu} \quad (3).$$

a) Identify ${}_Z^AX$ and ${}_{Z_1}^{A_1}X_1$.

b) Write down the global (over all) balanced equation of the nuclear reaction between a uranium 238 nucleus and a neutron leading to plutonium 239. [This reaction is denoted as reaction (4)].

c) Specify for each of the preceding reactions whether it is spontaneous or provoked.

3) The plutonium ${}_{94}^{239}Pu$ may react with a neutron according to the following reaction :

$${}_{94}^{239}Pu + {}_0^1n \rightarrow {}_{42}^{102}Mo + {}_{52}^{135}Te + 3\,{}_0^1n. \quad (5)$$

a) Calculate, in MeV/c^2, the mass defect Δm in this reaction.

b) Deduce , in MeV, the amount of energy E liberated by the fission of one plutonium nucleus.

c) Calculate**,** in joules, the energy liberated by the fission of one kilogram of plutonium.

4) We suppose that each fission reaction produces 3 neutrons. Using the preceding reactions, show that the role of one of the three neutrons agrees with the statement of the selection: "*…. produce, starting from uranium 238 an amount of fissionable material that is equal or exceeds what the reactor consumes…"*

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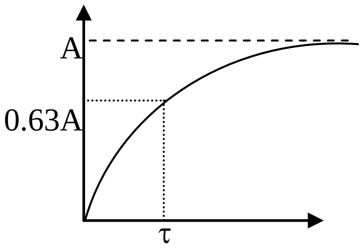
First exercise (7.5 points)

Part of the Q	Answer	Mark
A.1	The linear momentum of the system is conserved during the collision $m_2\overrightarrow{V_2} + \vec{0} = (m_1 + m_2)\vec{V}_0$ $\Rightarrow V_0 = \dfrac{m_2}{m_1 + m_2} V_2$; $V_0 = \dfrac{500}{600}\times 0.48 = 0.40$ m/s	
A.2.a	ME = ½ Mv^2 + ½ kx^2 ; $PE_g = 0$, t = 0 $\Rightarrow$ x = 0 , V = V_0 $ME(t_0 = 0)$ = ½ M V_0^2 = ½ ×0.6×$(0.4)^2$ = 0.048 J ;	
A.2.b	ME = ½ $(m_1 + m_2)$ v^2 + ½ kx^2	
A.2.c	No friction $\Rightarrow$ ME = constant $\Rightarrow$½ $(m_1 + m_2)$ v^2 + ½ kx^2 = ½ $(m_1 + m_2)$ V_0^2 . For v = 0, $X_m^2 = \dfrac{M}{k} V_0^2 = \dfrac{0.600}{25}(0.4)^2 \Rightarrow X_m = 0.062$ m = 6.2 cm.	
A.3a)	ME =½ $(m_1 + m_2)$ v^2 + ½ kx^2 = constant at any instant. $\dfrac{dME}{dt} = 0 = (m_1 + m_2)\,vx'' + kxv$ and $v \neq 0$ during oscillations $\Rightarrow x'' + \dfrac{k}{(m_1 + m_2)}x = 0.$	
A.3.b.i	$x = X_m \sin(\omega_0 t + \varphi)$; $v = x' = X_m\,\omega_0\cos(\omega_0 t + \varphi)$; $x'' = -X_m\,\omega_0^2\sin(\omega_0 t + \varphi)$. Replacing: $-X_m\,\omega_0^2\sin(\omega_0 t + \varphi) + \dfrac{k}{M} X_m \sin(\omega_0 t + \varphi) = 0 \Rightarrow \omega_0^2 = \dfrac{k}{M}$ $\Rightarrow$ The proper angular frequency is $\omega_0 = \sqrt{\dfrac{k}{M}} = \sqrt{\dfrac{25}{0.6}} = 6.45$ rd/s. At the instant $t_0 = 0$, $V_0 = 0.40$ m/s $\Rightarrow 0.4 = X_m \times 6.45\cos(\varphi)$ and $x_0 = 0$ $\Rightarrow A\sin\varphi = 0 \Rightarrow \sin\varphi = 0 \Rightarrow \varphi = 0$ or π But $\cos(\varphi) > 0 \Rightarrow \varphi = 0$ rd For $\varphi = 0$, $X_m = \dfrac{0.4}{6.45} = 0.062$ m = 6.2 cm. We obtain x (cm) = 6.2sin(6.45 t)	
A.3.b.ii	The proper period $T_0 = \dfrac{2\pi}{\omega_0} = 2\pi\dfrac{1}{6,45} = 0,974$ s $t_1 = T_0/4 = 0.243$ s.	

B.1	The loss of energy is $E = \lvert \Delta ME \rvert = \frac{1}{2} k(X_m^2 - X_{m1}^2) = 3.05\times10^{-3}$ J.	
B.2	Average power of the forces of friction: $P_{av} = \frac{E}{t_1} = 1.25\times10^{-2}$ W	
B.3.a	The frequency is f which is that of the vibrator, because the oscillator undergoes forced oscillations	
B.3.b.i	It is the phenomenon of resonance of amplitude.	
B.3.b.ii	$T \approx T_0$ and $f_1 \approx 1/T_0 \Rightarrow f_1 = 1.03$ Hz	

Second exercise (7.5 points)

Part of the Q	Answer	Mark
A.1	$i = \frac{dq_B}{dt} = C\frac{du_C}{dt}$.	
A.2	For $0 \le t \le T/2$, $u_g = E = u_R + u_C = Ri + u_C \Rightarrow RC\frac{du_C}{dt} + u_C = E$.	
A.3.a	$\frac{du_C}{dt} = A\frac{1}{\tau}e^{-\frac{t}{\tau}} \Rightarrow RC\,A\frac{1}{\tau}e^{-\frac{t}{\tau}} + A(1-e^{-\frac{t}{\tau}}). = E$ $\Rightarrow A\,e^{-\frac{t}{\tau}}(RC\frac{1}{\tau} - 1) + A - E = 0$, at any time $t \Rightarrow A = E$ and $\tau = RC$.	
A.3.b	See figure 	
A.4	For $T/2 \le t \le T$, $0 = u_R + u_C = Ri + u_C \Rightarrow RC\frac{du_C}{dt} + u_C = 0$. $u_C = E\,e^{-\frac{t}{\tau}}$ $\Rightarrow \frac{du_C}{dt} = -E\frac{1}{\tau}e^{-\frac{t}{\tau}}$ Replacing each quantity in the differential equation by its value, we obtain : $-RC\,E\frac{1}{\tau}e^{-\frac{t}{\tau}} + E\,e^{-\frac{t}{\tau}} = 0$; which is true, since $\tau = RC$.	
A.5.a	The minimum duration of charging mode or discharging mode so that u_C reaches its steady state must be 5τ.	
A.5.b	The minimum value of T must be 10τ	
B.1.a	The curve (3) corresponds to the charging mode of the capacitor since u_C increases with time.	
B.1.b	E = 5 V/div×2 div = 10V. The period T of the square signal = 2 ms/div×10 div = 20 ms.	
B.2.a	The period T of the square signal is now: 1ms/div×5 div = 5 ms. The duration of the charging and of the discharging is now less than 5τ. The capacitor has no more time to be completely charged and discharged.	
B.2.b	$T <<< 10\,\tau$, the curve becomes linear (straight line) during charging and	

	discharging.	

Third exercise (7.5 points)

Part of the Q	Answer	Mark
1.a	The energy of an atom can take only a certain number of discrete values	
1.b	$E = h\nu = \frac{hc}{\lambda}$.	
2.a	$E_n - E_1 = h\nu = \frac{hc}{\lambda} = -\frac{13.6}{n^2} - (-\frac{13.6}{1^2}) = 13.6\,(1 - \frac{1}{n^2}) = 13.6\,(\frac{n^2-1}{n^2})$ $\Rightarrow \lambda = \frac{hc}{13.6}(\frac{n^2}{n^2-1})$. $\lambda = \frac{6.62\times10^{-34}\times3\times10^{8}}{13.6\times1.6\times10^{-19}}(\frac{n^2}{n^2-1}) = 0.913\times10^{-7}\,(\frac{n^2-1}{n^2})$ m $\lambda = 91.3\,(\frac{n^2-1}{n^2})$ nm	
2.b.i	The energy of a photon being inversely proportional to its wavelength, minimum of energy corresponds to maximum $\lambda = \lambda_1$ $\Rightarrow$transition from n = 2 $\Rightarrow \lambda_1 = 91.3\,(\frac{4}{4-1}) = 122$ nm	
2.b.ii	maximum of energy corresponds to the largest n $\Rightarrow n = \infty \Rightarrow \lambda_2 = 91{,}3$ nm.	
2.b.iii	$91.3 \leq \lambda(\text{nm}) \leq 122$ $\Rightarrow$ The Lyman's series spectrum belongs to ultra-violet domain	
3.a	Is the maximum wavelength for the photoelectric effect to take place .	
3.b	The incident wavelength is such $91.3 \leq \lambda(\text{nm}) \leq 122$, it is then smaller than $\lambda_0 = 270$ nm, thus we have emission of electrons	
3.c	The relation of Einstein gives: $\frac{hc}{\lambda} = \frac{hc}{\lambda_S} + KE$ $\Rightarrow KE = \frac{hc}{\lambda} - \frac{hc}{\lambda_S} = hc(\frac{1}{\lambda} - \frac{1}{\lambda_S})$; $(KE)_{max} = b$ $b = hc(\frac{1}{\lambda_{min}} - \frac{1}{\lambda_S}) = 6.62\times10^{-34}\times3\times10^{8}\,(\frac{1}{91.3\times10^{-9}} - \frac{1}{270\times10^{-9}})$; $b = 0.725\times10^{-19}$ J = 0.453 eV $(E_C)_{min} = a$ $a = hc(\frac{1}{\lambda_{max}} - \frac{1}{\lambda_S}) = 6.62\times10^{-34}\times3\times10^{8}\,(\frac{1}{122\times10^{-9}} - \frac{1}{270\times10^{-9}})$; $a = 0.449\times10^{-19}$ J = 0.281 eV.	
3.d	In the relation $KE = \frac{hc}{\lambda} - \frac{hc}{\lambda_S}$; the values of λ are discrete $\Rightarrow$ the values KE form then a discontinuous succession $\Rightarrow$the kinetic energy of the electrons is then quantized	

Fourth exercise (7.5 points)

Part of the Q	Answer	Mark
1	*"… starting from uranium 238 an amount of fissionable material that is equal or exceeds what the reactor consumes since the final result would be the consumption of uranium 238 only which is more abundant than the uranium 235….."*	
2.a	${}^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{A}_{Z}X$. **(1)** A = 239 ; Z = 92 donc ${}^{A}_{Z}X$ est ${}^{239}_{92}U$ ${}^{239}_{92}U \rightarrow {}^{0}_{-1}e + {}^{A_1}_{Z_1}X_1 + {}^{0}_{0}\bar{\nu}$. **(2)** A_1= 239 ; Z_1= 93, donc ${}^{A_1}_{Z_1}X_1$ est ${}^{239}_{93}N_P$	
2.b	**(1) +(2) +(3)** $\Rightarrow$ ${}^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{239}_{94}P_U + 2\,{}^{0}_{-1}e + 2\,{}^{0}_{0}\bar{\nu}$ **(4)**	
2.c	**(1) :** Provoked reaction ; **(2)** and **(3) :** spontaneous**;** **(4) :** provoked**.**	
3.a	Δm = 0.2086 u = 194.31 MeV/c^2	
3.b	E = m c^2 = 194.31 MeV	
3.c	Mass of a plutonium 239nucleus is: 239 u = $239 \times 1.6605 \times 10^{-27}$ kg **=** 396.86×10^{-27} kg Number of nuclei contained in 1 kg of plutonium 239 is : $\dfrac{1}{396.86 \times 10^{-27}} = 2.52 \times 10^{24}$ nuclei The energy liberated: $2.52 \times 10^{24} \times 194.31 = 4.9 \times 10^{26}$ MeV = 7.83×10^{13} J.	
4	A neutron interacts with uranium 238 in order to form another nucleus of plutonium. This shows that the plutonium nuclei are in excess in the population of nuclei.	