وزارة التربية والتعليم العالي
المديرية العامة للتربية
دائرة الامتحانات

امتحانات الشهادة الثانوية العامة
فرع علوم الحياة

دورة سنة ٢٠٠٦ الاكمالية الاستثنائية

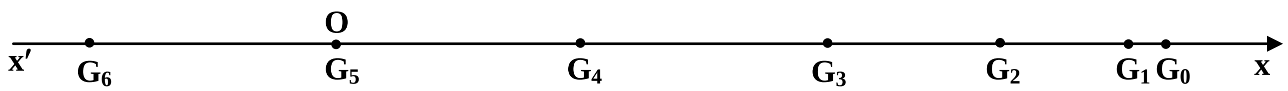
مسابقة في مادة الفيزياء
المدة: ساعتان

الاسم:
الرقم:

<u>This exam is formed of three exercises in three pages numbered from 1 to 3.</u>
<u>The use of a non-programmable calculator is recommended</u>.

<u>First exercise</u> : (6 ½ pts) <u>Horizontal mechanical oscillator</u>

Consider a mechanical oscillator that is formed of a solid (S) of mass m = 0.1 kg and a spring whose stiffness (force constant) is k. (S) may move, without friction, on a horizontal track with its center of mass G on a horizontal axis x′x .
An apparatus is used to register the positions of the center of mass G at successive instants separated by a constant time interval τ = 20 ms.
(S) is shifted , in the positive direction , from the equilibrium position O of G by a certain distance, and then is released without initial velocity at the instant $t_0 = 0$.
The above apparatus gives the positions G_0, G_1, G_2, G_3….of G at the instants $t_0 = 0$, $t_1 = \tau$, $t_2 = 2\tau$,
$t_3 = 3\tau$ …… respectively.



Some of the positions of G are given in the following table:

t	0	τ	2τ	3τ	4τ	5τ	6τ
OG = x(cm)	OG_0	OG_1= 9.53	OG_2 = 8.09	OG_3 = 5.88	OG_4 = 3.09	OG_5 = 0	OG_6= -3.09

1) At the instant t, the abscissa of G is x and the algebraic value of its velocity is v.
Write the expression of the mechanical energy of the system (oscillator, Earth) in terms of x ,v , m and k. Take the horizontal plane through G as a gravitational potential energy reference.
2) Derive the second order differential equation that governs the motion of G.
3) The solution of this differential equation may be written in the form:

$$x = X_m \sin(\omega_0 t + \varphi) \text{ where } X_m,\ \omega_0 \text{ and } \varphi \text{ are constants.}$$

a) Determine the expression of ω_0 in terms of m and k.
b) Determine the position of G for which the speed of (S) is maximum (V_{max}).
c) Applying the principle of conservation of mechanical energy, show that:

$$(V_{max})^2 = v^2 + \omega_0^2 x^2 .$$

4) Using the above table, show that:
a) the speed at the instant t_3 is 1.250 m/s ;
b) the maximum speed is V_{max} = 1.545 m/s.
5) Deduce the value of k.

Second exercise**: (7 pts)* ***The capacitor - A humidity sensor

In order to show evidence of the role of the capacitor in the humidity sensor, we connect up the circuit of figure 1.

This circuit is formed of a function generator (LFG) delivering across its terminals an alternating sinusoidal voltage of frequency f , a coil of inductance L = 0.07 H and of negligible resistance, a resistor of resistance R = 100 KΩ and a capacitor of capacitance C.

The voltage across the LFG is $u_{AM} = U_m \sin \omega t$,($\omega = 2\pi f$) .The circuit thus carries an instantaneous current given by: $i = I_m \sin(\omega t+\varphi)$

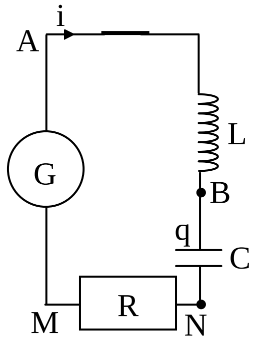


Figure 1

1) We denote by $u_C = u_{BN}$ the instantaneous voltage across the capacitor, by u_{AB} the voltage across the coil and by u_{NM} that across the resistor.

Show that:

a) $i = C\dfrac{du_C}{dt}$

b) u_C may be written in the form: $u_C = \dfrac{-I_m}{C\omega}\cos(\omega t + \varphi)$.

c) $u_{AB} = L\omega I_m \cos(\omega t + \varphi)$.

2) The relation: $u_{AM} = u_{AB} + u_{BN} + u_{NM}$ is valid for any t . Show, giving ωt a particular value, that:

$$\tan\varphi = \frac{\frac{1}{C\omega} - L\omega}{R}.$$

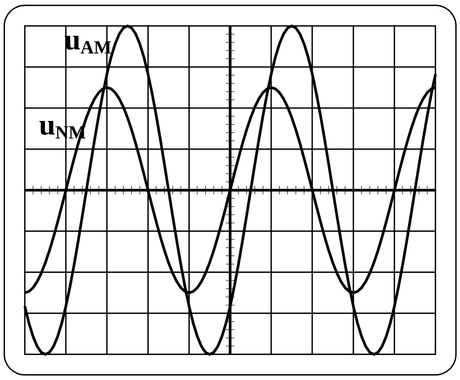


Figure 2

3) An oscilloscope, conveniently connected, displays the variations , as a function of time ,of u_{AM} and u_{NM} on the channels (Y_1) and (Y_2) respectively .These variations are represented in the waveforms of figure 2.

a) Redraw figure 1 showing the connections of the oscilloscope.

b) The waveform of u_{NM} represents the « image » of the current i. Why?

c) Find the value of f , knowing that the horizontal sensitivity is 5ms/division.

d) Determine the phase difference φ between i and u_{AM} .

4) Deduce the value of the capacitance C.

5) The frequency f is made to vary, keeping the same effective value of u_{AM} . It is noticed that, for a value f_1 of f, u_{AM} is in phase with i.

a) Give the name of the phenomenon that appears in the circuit.

b) Deduce, from what preceded, the relation among L, C and f_1.

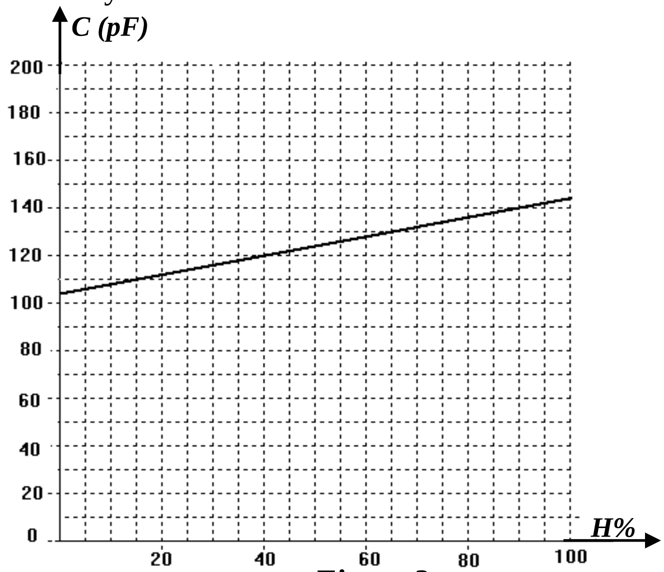


Figure 3

6) A commercial humidity sensor can be considered as a capacitor whose capacitance C increases when the rate of relative humidity H % of air increases.

The manufacturer provides the graph of the variation of C as a function of the rate of the relative humidity H % (Fig.3). ($1pF = 10^{-12}F$).

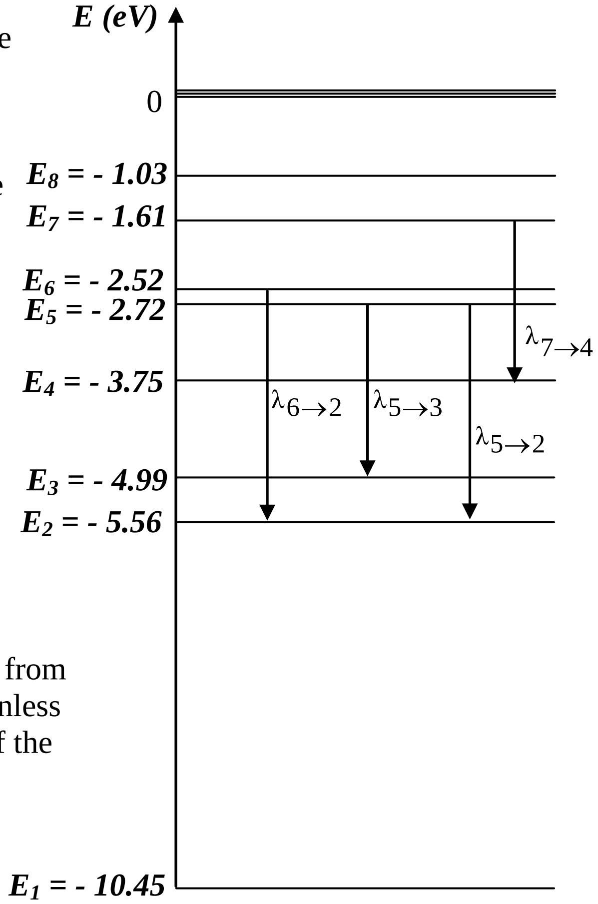
We replace the capacitor of the circuit of figure 1 by the sensor.

In order to measure the value of C, the frequency f is made to vary; we notice that the voltage u_{AM} and the current i are in phase for a frequency $f = 5.20\times10^4$ Hz.

Deduce the rate of relative humidity of air under the atmospheric conditions of the experiment.

<u>Third exercise</u>: (6 ½ pts) Emission spectrum of a mercury vapor lamp

The object of this exercise is to determine the visible emission spectrum of a mercury vapor lamp.
The adjacent diagram gives, in a simplified way, the energy level of the ground state , those of the excited states E_2, E_3, E_4, E_5, E_6, E_7 , E_8 and the ionization energy level E = 0 of the mercury atom.



<u>Given:</u>
Planck's constant $h = 6.62\times10^{-34}$ J.s;
speed of light in vacuum : $c = 3\times10^{8}$ m/s;
1 eV= 1.6×10^{-19} J;

I- Quantization of the energy of the atom

1) The energy of the mercury atom is quantized. What is meant by "quantized energy"?

2) a) What is meant by « ionizing » an atom ?

b) Calculate, in eV, the ionization energy of a mercury atom taken in the ground state.

***3)* Interaction photon-atom.**

A photon cannot cause the transition of an atom from an energy level E_P to a higher energy level E_n unless its energy is exactly the same as the difference of the energies (E_n - E_P) of the atom.

The mercury atom being in the ground state.

a) Determine the maximum wavelength of the wave associated to a photon capable of exciting this atom.

b) The mercury atom is hit with a photon of wavelength $\lambda_1 = 2.062\times10^{-7}$ m.

i) Show that this photon cannot be absorbed.

ii) What is then the state of this atom?

c) The atom receives now a photon of wavelength λ_2. The atom is thus ionized and the extracted electron is at rest. Calculate λ_2.

II- Emission by a mercury vapor lamp

For an electron to cause a transition of an atom from an energy level E_P to a higher energy level E_n, its energy must be at least equal to the difference of the energies (E_n- E_P) of the atom.
During one electron-atom collision, the atom absorbs, from the electron , an amount of energy enough to ensure a transition. The rest of the energy is carried by the electron as kinetic energy.
When the mercury vapor lamp is under a convenient voltage, an electric discharge takes place. Some electrons, each of kinetic energy 9 eV, moving in the vapor of mercury between the electrodes of the lamp , hit the gaseous atoms giving them energy. For that lamp, the atoms are initially in the ground state.

1) Verify that an atom may not overpass the energy level E_7.

2) The visible emission spectrum due to the downward transition of the mercury atom, is formed of four rays of wavelengths: $\lambda_{7\to4}$; $\lambda_{6\to2}$; $\lambda_{5\to2}$; $\lambda_{5\to3}$ ***(refer to the diagram).***

Determine the wavelengths of the limits of the visible spectrum of the mercury vapor lamp.

أسس التصحيح   لصف علوم الحياة.   المادة فيزياء.   دورة ٢٠٠٦ الاستثنائية

<u>First exercise</u> (6 ½ pts)

1) ME = KE + PE_g + PE_{el} = ½ mv^2 + ½ kx^2 + 0 **(1/2 pt)**

2) Friction is neglected

=> $\frac{dE_m}{dt} = 0 = mx'x'' + kxx'$ => $x'' + \frac{k}{m}x = 0$.**(1/2 pt)**

3) a- $x' = X_m\,\omega_0\cos(\omega t + \varphi) \Rightarrow$
$x'' = -X_m\,\omega_0^2\sin(\omega t + \varphi)$; replace x'' and x in the obtained differential equation, we obtain :

$-X_m\,\omega_0^2\sin(\omega t + \varphi) + \frac{k}{m}X_m\sin(\omega t + \varphi) = 0$

$\Rightarrow X_m\sin(\omega t + \varphi)\,(-\omega_0^2 + \frac{k}{m}) = 0 \Rightarrow \omega_0 = \sqrt{\frac{k}{m}}$

(1 pt)

b- v = $x' = X_m\,\omega_0\cos(\omega t + \varphi)$; |v| is max when

$\cos(\omega t + \varphi) = \pm 1 \Rightarrow x = 0$.

(or we apply the conservation of ME) **(1 pt)**

c- ME = cte = ME (at point O) = ME_t (any point of abscissa x and speed v). $\Rightarrow$½ m $(V_{max})^2$ =½ mv^2 + ½ kx^2

=> $(V_{max})^2 = v^2 + \omega_0^2 x^2$ **(1pt)**

4) a- $v_3 = \frac{G_4G_2}{2\tau}$ = 1.250 m/s. **(1/2pt)**

b- $V_{max} = v_O = \frac{G_6G_4}{2\tau}$ = 1.545 m/s. **(1/2pt)**

5) By using the relation $(V_{max})^2 = v^2 + \omega_0^2 x^2$ at the point of abscissa x_3 = 5.88 cm, we obtain : ω_0 = 15.44 rad/s.

(1pt)

But $\omega_0 = \sqrt{\frac{k}{m}}$ $\Rightarrow$ k = 23.85 N/m. **(1/2 pt)**

<u>Second exercise</u>: (7 pts)

1) a- i = dq / dt and q = C u_C $\Rightarrow$ i = Cdu_C / dt. **(1/2 pt)**

b- $u_C = \frac{1}{C}\int i\,dt = \frac{-I_m}{C\omega}\cos(\omega t + \varphi)$. **(1/2 pt)**

c- $u_{AB} = L\,di/dt = L\omega I_m\cos(\omega t + \varphi)$ **(1/2pt)**

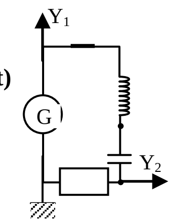
2) $u_{AM} = u_{AB} + u_{BN} + u_{NM}$

$\Rightarrow U_m\sin\omega t =$
$L\omega I_m\cos(\omega t + \varphi) - (I_m / C\,\omega)\cos(\omega t + \varphi) + RI_m\sin(\omega t + \varphi)$.

For ωt = 0 $\Rightarrow$ $0 = L\omega I_m\cos\varphi - (I_m/C\,\omega)\cos\varphi + RI_m\sin\varphi$

$\Rightarrow \tan\varphi = \frac{\frac{1}{C\omega} - L\omega}{R}$. **(1 pt)**

3) a- Branching of the oscilloscope. **(1/2 pt)**



b- u_{CM} = Ri i = u_{NM}/cte $\Rightarrow$ the curve of u_{NM} represents the « image » of i **(1/2 pt)**

c- T $\rightarrow$ 4 div $\Rightarrow$ T = 20 ms $\Rightarrow$ f = 50 Hz **(1/2 pt)**

d- $|\varphi| = \frac{\pi}{4}$ rad **(1/2 pt)**

4) $\omega = \frac{2\pi}{T}$ =100 π, the relation $\tan\varphi = \frac{\frac{1}{C\omega} - L\omega}{R}$

$\Rightarrow$ C = 32 nF **(1/2pt)**

5) a- Current resonance **(1/2pt)**

b- At current resonance : φ = 0 $\Rightarrow \frac{1}{C\omega} - L\omega = 0 \Rightarrow 4$
$\pi^2 LCf_1^2 = 1$ **(1/2pt)**

6) C = 132 pF **.** Graphically for C=132 pF, the relative humidity of air is 70 %. **(1 pt)**

<u>Third exercise :</u> (6 ½ pts)

I -

1) only specific values of energy are allowed **(1/2 pt)**

2) a- giving the atom an energy to extract an electron **(1/2 pt)**
b- E(ionization) = E – E_1= 0 – (-10.45) = 10.45 eV. **(1/2 pt)**

3) a- $\lambda = \frac{hc}{E_n - E_1}$.

λ_{max} correspond $(E_n)_{min} \Leftrightarrow n = 2 \Rightarrow \lambda_{max} = 2.54 \times 10^{-7}$ m **(1 pt)**

b- i) For λ_1 , the energy of the photon is:

$E = \frac{hc}{\lambda} = 9.63\times10^{-19}$ J = 6.02 eV; the energy level of the atom must be E_1 + E = - 4,43 eV ; but this level does not exist in the energy diagram , so the photon is not absorbed **(1 pt)**

ii) The atom remains in the ground state **(1/4 pt)**

c- W= 10.45 eV $\Rightarrow \lambda_2 = 1.188\times10^{-7}$ m. **(3/4 pt)**

II-1- E_1 + 9 = (- 10.45) + 9 = -1.45eV < E_8 **(1 pt)**

2- $(\Delta E)_{6\to2}$ = 3.04 eV; $(\Delta E)_{5\to3}$ = 2,27 eV; $(\Delta E)_{7\to4}$ = 2.14 eV

$(\Delta E)_{5\to2}$ = 2.84 eV. $(\Delta E)_{max}$ = 3.04 eV et $(\Delta E)_{min}$ = 2.14 eV

$\lambda = \frac{hc}{\Delta E}$

$\lambda_{min} \Rightarrow (\Delta E)_{max} = E_6 - E_2 \Rightarrow \lambda_{6\to2}$= 408.3 nm

$\lambda_{max} \Rightarrow (\Delta E)_{min} = E_7 - E_4 \Rightarrow \lambda_{7\to4}$= 580.0 nm **(1pt)**