مسابقة في مادة الفيزياء	الاسم:
المدة ساعتان	الرقم:

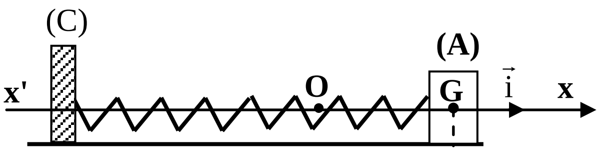
This exam is formed of three exercises in three pages.
The use of non-programmable calculators is recommended.

First exercise: (7 points)

Mechanical oscillations

The aim of this exercise is to study two types of oscillations of a horizontal elastic pendulum.

On a table, we consider a puck (A), of mass m = 200 g, fixed to one end of a massless spring of un jointed turns, and of stiffness k = 80 N/m; the other end of the spring is attached to a fixed support (C) (adjacent figure).



(A) slides on a horizontal rail and its center of inertia G can move along a horizontal axis x'Ox. At equilibrium, G coincides with the origin O of the axis x'x.

At an instant t, the position of G is defined, on the axis $(O, \vec{i})$, by its abscissa $x = \overline{OG}$; its velocity $\vec{v} = v\,\vec{i}$ where $v = x' = \dfrac{dx}{dt}$.

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

A – Free un-damped oscillations

Suppose that in this part, the forces of friction are negligible.

At the instant $t_0 = 0$, G, initially at O, is launched with a velocity $\vec{V_0} = V_0\,\vec{i}$ ($V_0 = 2.5$ m/s).

1) Determine, at $t_0 = 0$, the mechanical energy of the system [(A), spring, Earth].

2) Write, at an instant t, the expression of the mechanical energy of the system [(A), spring, Earth] in terms of x, k, m and v.

3) **a)** Derive the differential equation, in x, that describes the motion of G.

b) Deduce the value of the proper angular frequency ω_o and that of the proper period T_o of the oscillations.

4) The solution of the previous differential equation is of the form $x = X_m\cos(\omega_o t + \phi)$. Determine the values of the constants X_m and ϕ .

B – Free damped oscillations

We suppose now that (A) is submitted to a force of friction $\vec{f}$ of average value $f_{av.}$

1) The center of inertia G is shifted by $X_{0m} = 12.5$ cm from O. Then (A) is released at the instant $t_0 = 0$ without initial velocity. G passes through O, for the first time, at the instant $t_1 = 0.085$ s with a speed $V_1 = 2$ m/s.

a) Determine the variation of the mechanical energy of the system [(A), spring, Earth] between the instants t_0 and t_1.

b) Deduce f_{av} between the instants t_0 and t_1.

2) In order to drive the oscillations of (A), an appropriate set-up supplies the oscillator an average power P_{av}.

a) What is meant by "drive the oscillations"?

b) Calculate P_{av} between the instants t_0 and t_1.

Second exercise: (7 points)

Identification of two electric components

Consider two electric components (D_1) and (D_2), a generator (G) delivering an alternating sinusoidal voltage of angular frequency $\omega = 100\pi$ rd/s and a resistor (R) of resistance $R = 100\ \Omega$. One of the two components is a coil of inductance L and of negligible resistance; the other is a capacitor of capacitance C.

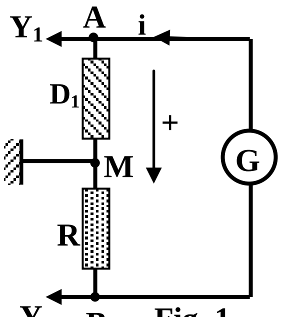


Fig. 1

Take: $0.32\pi = 1$

A – Characteristic of the component (D_1)

We connect in series the component (D_1), the generator (G) and the resistor (R) (Fig.1).

An oscilloscope is used to display, on channel Y_1, the voltage u_{AM} across (D_1) and, on the channel Y_2, the voltage u_{MB} across the resistor, the button "Inv" of channel Y_2 being pushed. The obtained waveforms are represented in figure 2.

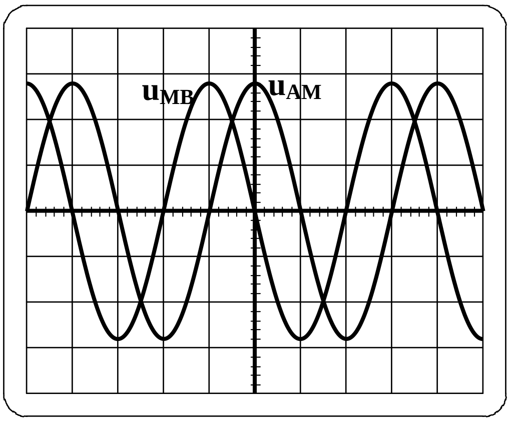
1) Using the waveforms of figure 2, show that (D_1) is a capacitor.

2) Referring to the waveforms in figure 2. Determine:

- **a)** the maximum value $U_{m(R)}$ of the voltage u_{MB} and deduce the maximum value I_m of the current i carried by the circuit;
- **b)** the maximum value $U_{m(D1)}$ of the voltage u_{AM}.

3) Knowing that the expression of i is: $i = I_m\cos(\omega t)$, show that the expression of u_{AM} is of the form: $u_{AM} = \frac{I_m}{C\omega}\sin(\omega t)$.

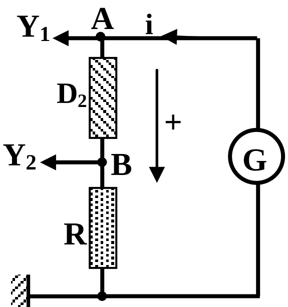
4) Deduce the value of C.



S_V = 5V/div for both channels **Fig. 2**

B – Characteristic of the component (D_2)

(D_2) is then a coil. We connect the set-up of figure 3. We display the voltage $u_{AM} = u_G$ on channel Y_1 and the voltage u_{BM} on channel Y_2. The obtained waveforms are shown on figure 4.



M **Fig. 3**

1) Show that the curve (a) represents u_G.

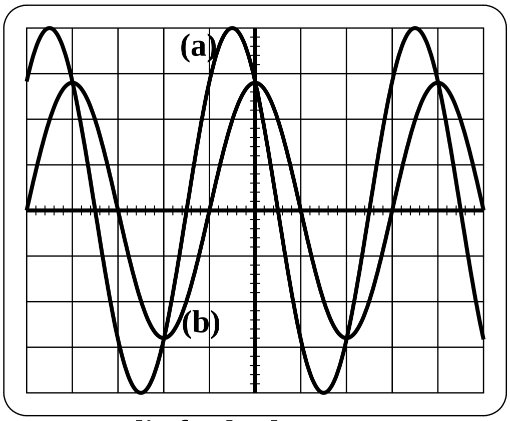
2) Referring to the waveforms of figure 4, determine:

- **a)** the maximum value $U_{m(R)}$ of the voltage u_{BM} across the resistor and deduce the maximum value I_m of the current i carried by the circuit;
- **b)** the maximum value $U_{m(G)}$ of the voltage across the generator;
- **c)** The phase difference φ between the current i and the voltage u_G across the generator.

3) Knowing that $i = I_m\cos(\omega t)$:

- **a)** determine the expression of the voltage of u_{AB} across the coil in terms of L, I_m, ω and t;
- **b)** write the expression of the voltage u_G as a function of time.

4) Applying the law of addition of voltages between A and M and giving the time t a particular value, determine the value of L.



S_V = 5V/div for both channels **Fig. 4**

<u>Third exercise</u>: (6 points)

Hydrogen atom

The aim of this exercise is to study Lyman series of the hydrogen atom. The energy levels of this atom are given by the relation:

$E_n = -\dfrac{E_0}{n^2}$, with $E_0 = 13.6$ eV and n is whole non zero and positive number.

Given :

$h = 6.62\times10^{-34}$ J·s; $c = 3\times10^{8}$ m/s; 1 eV = 1.6×10^{-19} J; 400 nm $\le \lambda_{visible} \le$ 800 nm.

A – Energy levels of the hydrogen atom

1) a) Calculate the energy of the hydrogen atom when it is:

i. in the fundamental state;

ii. in the first excited state;

iii. in the ionized state.

b) The energy levels of the hydrogen atom are quantized. Justify.

2) This atom, taken in a given energy level E_p, receives a photon of energy E and of wavelength λ in vacuum. Thus, the hydrogen atom passes to an energy level E_m such that m > p.

a) Write the relation among E, E_p and E_m.

b) Deduce the relation among E_0, p, m, h, c and λ.

B – The absorption «Lyman α» ray

Certain galaxies that are very far have in their center a very luminous nucleus called "quasar". The quasar spectrum contains emission and absorption rays. In the absorption series of Lyman, the atom passes from the fundamental state to an excited state of energy E_n by absorbing a photon of wavelength λ.

1) Determine the relation among h, c, λ, E_0 and n.

2) The wavelength of an absorption ray of the Lyman's series is given by the relation:

$$\frac{1}{\lambda} = R_H\left(1 - \frac{1}{n^2}\right) ; \ R_H \text{ is the Rydberg constant.}$$

a) Show that $R_H = \dfrac{E_0}{hc}$.

b) Deduce the value of R_H in the SI units.

3) a) Determine the longest wavelength of the absorption series of Lyman.

b) Deduce to which of the following domains, do the rays of Lyman series belong to: visible, ultraviolet or infrared domain.

4) «Lyman α», of wavelength $\lambda_\alpha = 121.7$ nm, is one of the rays of the absorption spectrum of Lyman series.

This ray permits us to detect gaseous clouds that surround a quasar.

Indicate the transition of the hydrogen atom that corresponds to the absorption of «Lyman α».

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مشروع معيار التصحيح	مسابقة في مادة الفيزياء المدة ساعتان	الاسم: الرقم:

First exercise (7 points)

Part of the Q	Answer	Mark
A.1	$ME_0 = KE0 + PEg_0 + PEe_0$; PEg = 0 (on the reference) and $PEe_0 = 0$ ($x_0 = 0$) Therefore: $ME_0 = KE_0 = \frac{1}{2}mv^2 = 0.625$ J	0.75
A.2	$ME = KE + PEe = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$	0.5
A.3.a	No frictional forces (no non-conservative forces), ME is conserved $\Rightarrow \frac{dME}{dt} = 0 \Rightarrow \frac{1}{2}m2v\ddot{x} + \frac{1}{2}k2xv = 0 \Rightarrow \ddot{x} + \frac{k}{m}x = 0$	0.75
A.3.b	$\ddot{x} + \frac{K}{m}x = 0$ similar to $\ddot{x} + \omega_0^2 x = 0$ $\omega_o = \sqrt{\frac{k}{m}} = 20$ rd/s and $T_o = 2\pi\sqrt{\frac{m}{k}} = 0.314$ s.	1.00
A.4	$x = X_m \cos(\omega_o t + \varphi)$; Fort = 0 ; $x_0 = 0 \Rightarrow \cos\varphi = 0 \Rightarrow \varphi = \pm\frac{\pi}{2}$ $x' = v = -\omega_0 Xm \sin(\omega_0 t + \varphi)$; For t = 0 ; $V_0 = -\omega_0 Xm \sin(\varphi)$ $\Rightarrow \sin(\varphi) < 0 \Rightarrow \varphi = -\frac{\pi}{2}$rd we replace φ in $V_0 = -\omega_0 Xm \sin(\varphi)$ we obtain $X_m = \frac{V_0}{\omega_0} = 0.125$ m **<u>Or</u>** : At maximum elongation x= X_m and v = 0 $\Rightarrow ME = \frac{1}{2}kX_m^2$ ME conserved $\Rightarrow \frac{1}{2}kX_m^2 = 0.625 \Rightarrow X_m = 0.125$m = 12.5 cm.	1.5
B.1.a	When passing through 0, $P.E_e = 0$ therefore ME = KE and $\Delta ME = ME_1 - ME_0 = KE_1 - PE_{e0} = ½\, m v_1^2 - ½\, k x_{0m}^2$ $= \frac{1}{2}0.2 \times 2^2 - 0.625 = -0.225$J	0.75
B.1.b	$\Delta ME = W(\vec{f}) \Rightarrow -0.225 = -f_m X_m \Rightarrow f_m = 1.8$ N	0.75
B.2.a	To provide the oscillator with the necessary energy needed to compensate for the losses of energy and maintain its amplitude constant.	0.5
B.2.b	$P_{av} = \frac{\lvert\Delta E_m\rvert}{\Delta t} = \frac{0.225}{0.085} = 2.647$ W.	0.5

Second exercise (7 points)

Part of the Q	Answer	Mark
A.1	$u_{MB} = u_R$ (image of the current) leads u_{AM}, then D_1 is a capacitor	**0.5**
A.2.a	$U_m(R) = 2.8\ div \times 5 = 14\ V = RI_m$ then $I_m = 0.14\ A$	**0.75**
A.2.b	$U_m(D1) = 2.8\ div \times 5 = 14\ V$	**0.25**
A.3	$i = \frac{dq}{dt} = C\frac{du_c}{dt}$; $du_c = \frac{1}{C}idt$; $u_c = \frac{1}{C}\int i.dt = \frac{1}{C}\int I_m\cos(\omega t).dt = \frac{I_m}{C\omega}\sin(\omega t)$	**0.75**
A.4	$U_m(AM) = \frac{I_m}{C\omega} = 14$ then $C = 32\times10^{-6}$ F	**0.75**
B.1	The amplitude of the graph (a) > than that of (b) and S_v is the same $\Rightarrow$ (a) represents u_{AM} **<u>Or</u>** (a) leads (b), (a) represents $u_{AM} = u_G$ and this is a RL circuit	**0.50**
B.2.a	$U_m(BM) = 2.8\ div \times 5 = 14\ V = RI_m$ then $I_m = 0.14\ A$	**0.5**
B.2.b	$U_{m(G)} = 4\ div \times 5 = 20\ V$	**0.25**
B.2.c	i lags u_{AM}, $\varphi = \frac{2\pi \times 0.5div}{4div} = \frac{\pi}{4}$ rd	**0.5**
B.3.a	$u_{AB} = L(\frac{di}{dt}) = - L\omega I_m\sin(\omega t)$	**0.5**
B.3.b	$u_{AM} = 20\cos(\omega t + \frac{\pi}{4})$	**0.5**
B.4	$u_G = = u_L + u_R$ $\Rightarrow 20\cos(\omega t+ \frac{\pi}{4}) = - L\omega I_m\sin(\omega t) + RI_m\cos(\omega t)$, $\omega t = \frac{\pi}{2} \Rightarrow 20\sin(\frac{\pi}{2}+\frac{\pi}{4}) = - L\omega I_m \Rightarrow L = 0.32$ H	**1.25**

Third exercise (6 points)

Part of the Q	Answer	Mark
A.1.a.i	For n = 1, $E_1 = -\frac{13.6}{1} = -13.6$ eV	**0.25**
A.1a.ii	For n = 2, $E_2 = -\frac{13.6}{4} = -3.4$ eV	**0.25**
A.1.a.iii	In ionized state $n=\infty$, $E_\infty = 0$ eV	**0.25**
A.1.b	The atom absorbes energy of specific value (discontinous)	**0.5**
A.2.a	$E = E_m - E_p$.	**0.5**
A.2.b	$E = \frac{hc}{\lambda} \Rightarrow \frac{hc}{\lambda} = -\frac{E_0}{m^2} + \frac{E_0}{p^2} = E_0(\frac{1}{p^2} - \frac{1}{m^2})$ $\Rightarrow \frac{hc}{\lambda} = E_0(\frac{1}{p^2} - \frac{1}{m^2})$	**0.75**
B.1	$E_n - E_1 = \frac{hc}{\lambda} \Rightarrow -\frac{E_0}{n^2} + E_0 = \frac{hc}{\lambda}$ $\frac{hc}{\lambda} = E_0(1 - \frac{1}{n^2})$	**0.5**
B.2.a	$\frac{hc}{\lambda} = E_0(1 - \frac{1}{n^2}) \Rightarrow \frac{1}{\lambda} = \frac{E_0}{hc}(1 - \frac{1}{n^2})$, $\Rightarrow R_H = \frac{E_0}{hc}$	**0.5**
B.2.b	$R_H = \frac{13.6 \times 1.6 \times 10^{-19}}{6.62 \times 10^{-34} \times 3 \times 10^8} = 1.096 \times 10^7 \text{ m}^{-1}$.	**0.5**
B.3.a	For the wavelength to be maximum, the energy $E = E_n - E_1$ is minimum $\frac{hc}{\lambda_{max}} = E_2 - E_1 \Rightarrow \lambda_{max} = 1.217 \times 10^{-7} \text{m} = 121.7 \text{nm}$ Or n = 2$\Rightarrow \frac{1}{\lambda_2} = 1.096 \times 10^7 (1 - \frac{1}{2^2}) = 8.217 \times 10^7 \text{ m}^{-1} \Rightarrow$ $\lambda_{max} = 1.217 \times 10^{-7}$ m = 121.7 nm.	**1**
B.3.b	The spectrum domain to which belong the rays of Lyman series is the ultraviolet domain, since the largest wavelength is: $\lambda_{Lyman} <$ 400 nm.	**0.50**
4	The concerned transition is n = 1 $\rightarrow$ n = 2, because $\lambda_\alpha = \lambda_{max}$	**0.5**