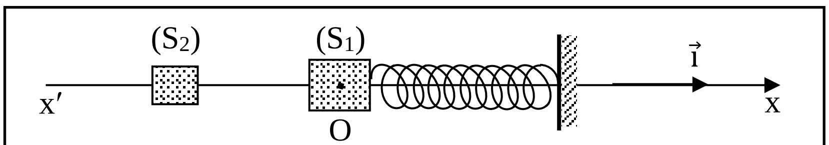
المركز التربوي للبحوث والإنماء	الهيئة الأكاديميّة المشتركة قسم: العلوم	المادة: الفيزياء – لغة إنكليزية الشهادة: الثانوية العامّة الفرع: علوم الحياة نموذج رقم: 1 / 2019 المدّة: ساعتان

This test includes three mandatory exercises. The use of non-programmable calculators is allowed.

Exercise 1 (6 points) Horizontal mechanical oscillator

The aim of this exercise is to determine the stiffness k of the spring (R) of a horizontal mechanical oscillator. This oscillator is formed of a particle (S_1) of mass M = 400 g and the spring (R) of negligible mass and of stiffness k.

The center of mass G of (S_1) may move along a horizontal straight axis x'Ox; O is at the equilibrium position of G, the spring being unstretched, as shown in (Doc 1). Neglect any force of friction.



(Doc 1)

1) Setting the oscillator in motion

(S_1) is initially at rest and G is at O. To set (S_1) in motion, a particle (S_2), of mass $m = \frac{M}{2}$, is launched towards (S_1) along the axis x'Ox. Just before the collision, (S_2) was moving with the velocity $\overrightarrow{V_2} = V_2\vec{i}$ (V_2 = 0.75 m/s). Just after the collision, (S_1) and (S_2) stick together to form a system (S) of mass M_S and of center of mass G. Thus, (S) acquires the velocity $\overrightarrow{V_0} = V_0\vec{i}$.

1-1) Specify the physical quantity that remains conserved during this collision.

1-2) Write the equation that expresses the preceding conservation.

1-3) Show that V_0 = 0.25 m/s.

2) Energetic study of the un-damped oscillator

(S) is set in motion, just after the collision, with the velocity $\overrightarrow{V_0} = V_0\vec{i}$ at the instant t_0 = 0. At an instant t, the position of G is defined by its abscissa $x = \overline{OG}$ and the algebraic value of its velocity is $v = x' = \frac{dx}{dt}$.

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

2-1) Write, at an instant t, the expression of the mechanical energy ME of the system [(S), (R), Earth].

2-2) Derive the differential equation that describes the motion of G as a function of time.

2-3) We suppose that the time equation of motion of G is written as:
$x = X_m \sin(\omega_0 t)$ (x in m; t in s), where X_m is a positive constant.

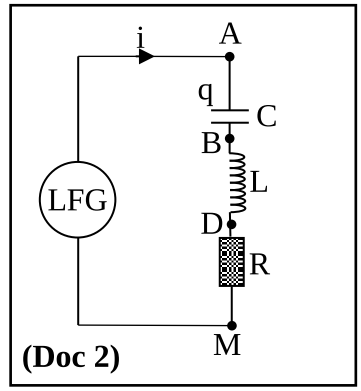
2.3.1) Determine the expression of ω_0.

2.3.2) During the motion of (S), G oscillates between two extreme positions A and B, 20 cm apart. Determine the value of k.

2.3.3) G passes through the point C of abscissa x_1 = -5.0 cm for the second time at the instant t_1. Determine t_1.

Exercise 2 (7 points) Determination of the characteristics of electric components

The aim of this exercise is to determine the characteristics R, L and C respectively of a resistor, a coil of negligible resistance and a capacitor. For this, we perform two experiments. Take: $\pi^2 = 10$.



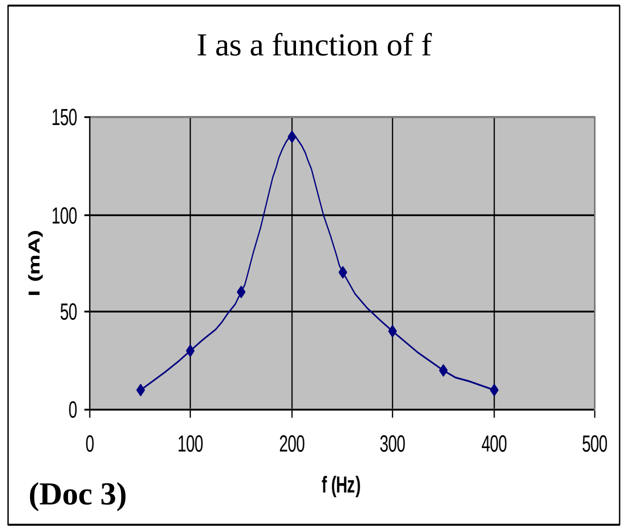
(Doc 2)

1) 1st experiment

Consider a series circuit (Doc 2) that consists of an LFG which delivers across its terminals an alternating sinusoidal voltage of effective value U and of adjustable frequency f, a resistor of resistance R, a coil of inductance L and of negligible resistance, a capacitor of capacitance C and an ammeter.

A voltmeter, connected across the terminals of the LFG, reads a constant value of U = 21 V.

We give f different values and we register, for each value, the effective current carried by the circuit. We obtain the plotted graph of (Doc 3) giving the variations of I as a function of f.



(Doc 3)

1-1) Specify the name of the physical phenomenon that takes place for f = 200 Hz.

1-2) Indicate then the proper frequency f_0 of this circuit.

1-3) Deduce the value of R.

1-4) Show that the first relation between L and C is: $LC = 0.625\times10^{-6}$ SI.

2) 2nd experiment

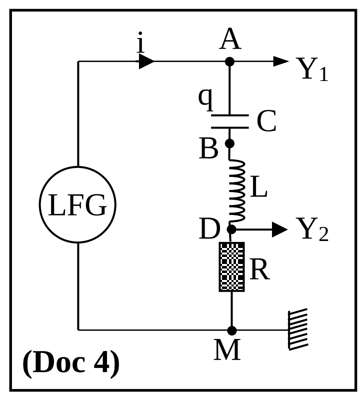
We consider the RLC series circuit shown in (Doc 4) where R = 150 Ω.

The expression of the voltage across the terminals of the LFG is: $u_{AM} = U_m \sin(2\pi f t)$.

The circuit thus carries an alternating sinusoidal current i.

The oscilloscope is connected to display the voltage u_{AM} across the LFG and the voltage u_{DM} across the resistor. (Doc 5) shows the waveforms (1) and (2) corresponding respectively to the voltages u_{AM} and u_{DM}, the frequency of u_{AM} being adjusted to f = 50 Hz.

The vertical sensitivity on both channels is 5 V/division.



(Doc 4)

2-1) Calculate, referring to (Doc 5), the maximum voltage U_m across the LFG.

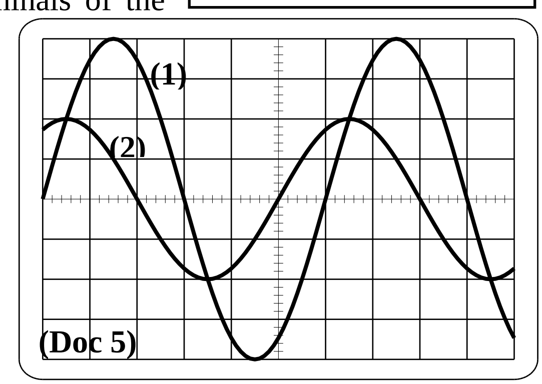
2-2) Determine, referring to (Doc 5), the expression of the voltage u_{DM}.

2-3) Deduce the expression of i.

2-4) Determine the expression of the voltage u_{AB} across the terminals of the capacitor.

2-5) Determine the expression of the voltage u_{BD} across the terminals of the coil.

2-6) Using the relation $u_{AM} = u_{AB} + u_{BD} + u_{DM}$, at any instant t, and giving t the value zero (t = 0), show that the second relation between L and C is: $10^4\pi^2 LC + 15000\pi C\sqrt{3} = 1$.



(Doc 5)

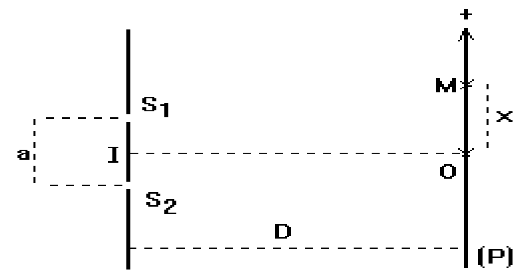
3) Conclusion

Determine the values of L and C from the above two relations between L and C.

Exercise 3 (7 points) Aspect of light

1) In a Young's set up, placed in air, the two slits S_1 and S_2, straight and parallel, have their centers, separated by a distance $a = S_1S_2 = 1$ mm. They are illuminated by a source S emitting a monochromatic light of wavelength, in air, $\lambda = 625$ nm, S being equidistant from S_1 and S_2.

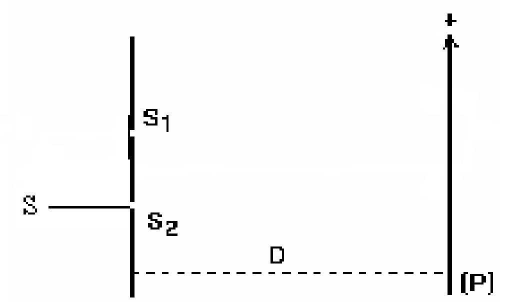
The screen of observation (P), parallel to the plane of (S_1S_2), is at a distance D = 1 m from I, the mid-point of [S_1S_2]. On (P), we consider a point M in the zone of interference whose position is defined by its abscissa x relative to the point O, the orthogonal projection of I on (P) as shown in (Doc 6).



(Doc 6)

1-1) Describe the fringes observed on the screen E.
1-2) Interpret the existence of the fringes.
1-3) Specify the nature of the fringe whose center is at O.
1-4) Give, in terms of D, a and x, the optical path difference at point M.
1-5) Derive the expression of the abscissa x of the centers of the dark fringes in terms of D, λ and a.
1-6) Deduce the inter-fringe distance in terms of λ, D and a.
1-7) Determine the type and order of the fringe whose center is at a distance of 3.75 mm from O.
1-8) A parallel plate, of thickness e and index of refraction n = 1.5, is placed in front of S_1. The optical path difference at a point M becomes: $\delta = (S_2M - S_1M) = \frac{ax}{D} - e(n-1)$. The center of the central bright fringe occupies now the position that was occupied previously by the center of the 2^{nd} dark fringe. Determine e.

2) Now, we cover the slit S_1. The source S, emitting the monochromatic radiation, is placed facing the slit S_2 whose width is of 0.10 mm as shown in (Doc 7).



(Doc 7)

2-1) Name the phenomenon that the light undergoes through the slit.
2-2) Calculate the width L of the central fringe obtained on the screen.

3) The preceding two optical phenomena show evidence of a particular aspect of light. Indicate this aspect.

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أسس التصحيح

Exercise 1 (6 points)　　　Horizontal mechanical oscillator

Question	Answer	Mark
1-1	The linear momentum of the system [(S_1), (S_2)] is conserved since the forces applied are the weights $M\vec{g}$ and $m\vec{g}$ and the normal reactions of the support $\overrightarrow{N_1}$ and $\overrightarrow{N_2}$ whose sum is nil.	½
1-2	$M_S\,\overrightarrow{V_0} = m\overrightarrow{V_2}$; along the x-axis, we may write: $mV_2 = M_SV_0$	½
1-3	$V_0 = mV_2/M_S = 0.200 \times 0.75 / 0.600 = 0.25$ m/s	½
2-1	$ME = KE + PE = ½\,M_Sv^2 + ½\,kx^2$　　($PE_g = 0$)	½
2-2	The conservation of the mechanical energy of the system [(S), (R), Earth] is due to the absence of any loss in energy (the only external force applied, whose point of application moves, is the normal reaction whose work is nil). $ME = ½\,M_Sv^2 + ½\,kx^2$ = constant $\forall t$ The derivative with respect to time gives: $\frac{dME}{dt} = M_Sv\frac{dv}{dt} + kx\frac{dx}{dt} = 0\ \forall t$; we get: $M_Sv\left(\frac{d^2x}{dt^2} + \frac{k}{M_S}x\right) = 0\ \forall t$; But v is not always nil. We obtain: $x'' + \frac{k}{M_S}x = 0$	1
2-3-1	$x = X_m\sin(\omega_0t)$; $v = x' = \omega_0X_m\cos(\omega_0t)$; $x'' = -\omega_0^2X_m\sin(\omega_0t) = -\omega_0^2x$; We get: $x'' + \omega_0^2x = 0$. Identifying with the previous equation, we obtain: $\omega_0^2 = \frac{k}{M_S} \Rightarrow \omega_0 = \sqrt{\frac{k}{M_S}}$	1
2-3-2	Since ME = constant, so : $ME(t_0 = 0) = ME(t) = ½\,M_SV_0^2 = 0.5 \times 0.6 \times (0.25)^2 = 0.01875$ J The amplitude is : $X_m = AB/2 = 10$ cm $= 0.10$ m ; for $x = X_m$, $v = 0$; $ME = PE_e = ½\,kX_m^2$ $0.01875 = ½\,k \times (0.10)^2$; $k = 3.75$ N/m	1
2-3-3	For $t = t_1$, $v_1 > 0$ since G moves in the positive direction, and $x_1 = -5.0$ cm. So: ($\omega_0 = \sqrt{\frac{3.75}{0.600}} = 2.5$ rad/s and $T_0 = 2\pi/2.5 \approx 2.51$ s). $x_1 = 0.10\sin(2.5t_1) = -0.050$ m and $v_1 = 0.25\cos(2.5t_1) > 0$ $\Rightarrow \sin(2.5t_1) = -0.50$ and $\cos(2.5t_1) > 0 \Rightarrow 2.5t_1 = -\pi/6$ or $2.5t_1 = 2\pi - \pi/6 = 11\pi/6$ The negative value of t_1 is rejected; Hence: $t_1 \approx 2.3$ s	1

Exercise 2 (7 points) **Determination of the characteristics of electric components**

Question	Answer	Mark
1-1	The circuit is thus the seat of the current resonance phenomenon since the effective current takes a maximum value I_0 for f = 200 Hz.	¼
1-2	The proper frequency is then f_0 = 200 Hz.	¼
1-3	The maximum value of the effective current is: I_0 = 140 mA. So: $R = \frac{U}{I_0} = \frac{21}{0.140} = 150\ \Omega$.	½
1-4	In this case: $f_0 = \frac{1}{2\pi\sqrt{LC}} = 200$; $LC = \frac{1}{4\times\pi^2\times4\times10^4}$ $LC = 0.625\times10^{-6}$ SI (1)	½
2-1	$U_m = S_v.Y = 4 \times 5 = 20$ V $u_{AM} = 20 \sin(100\pi t)$	½
2-2	The waveform (2), (u_{DM}), leads in phase the waveform (1), (u_{AM}), by $\lvert\varphi\rvert$. One period (2π) extends over 6 div; the phase difference $\lvert\varphi\rvert$ is relative to 1 div. So: $\lvert\varphi\rvert = \frac{2\pi\times1}{6} = \frac{\pi}{3}$ rad and $\omega = 2\pi f = 100\pi$ rad/s $U_{m2} = S_v.Y = 2 \times 5 = 10$ V and $u_{DM} = 10 \sin(100\pi t + \pi/3)$ (u_{DM} in V, t in s)	**1½**
2-3	Ohm's law gives: $i = \frac{u_{DM}}{R} = \frac{10}{150}\sin(100\pi t + \frac{\pi}{3})$; We get: $i = \frac{1}{15}\sin(100\pi t + \frac{\pi}{3}) = 0.067 \sin\left(100\pi t + \frac{\pi}{3}\right)$; (i in A, t in s).	½
2-4	$i = \frac{dq}{dt} = C\frac{du_{AB}}{dt}$ The voltage across the capacitor is written as: $u_{AB} = \frac{1}{C}\int i\,dt = -\frac{1}{1500\pi C}\cos(100\pi t + \frac{\pi}{3})$, the integration constant being nil since u_{AB} is an alternating sinusoidal voltage.	½
2-5	$u_{BD} = L\frac{di}{dt} = \frac{100}{15}\pi L \cos(100\pi t + \frac{\pi}{3})$	½
2-6	$u_{AM} = u_{AB} + u_{BD} + u_{DM}\ \ \forall t$ $20\sin(100\pi t) = (\frac{100}{15}\pi L - \frac{1}{1500\pi C})\cos(100\pi t + \frac{\pi}{3}) + 10\sin(100\pi t + \frac{\pi}{3})$ For t = 0 $0 = (\frac{100}{15}\pi L - \frac{1}{1500\pi C})\cos(\frac{\pi}{3}) + 10\sin(\frac{\pi}{3})$ $10^4\pi^2 LC + 15000\pi C\sqrt{3} = 1$ (2)	**1**
3	The equations (1) and (2) give: $\begin{cases} C = 1.15\times10^{-5} F = 0.115 \mu F \\ L = 0.0543\,H = 54.3\text{ mH} \end{cases}$	**1**

Exercise 3 (7 points) **Aspect of light**

Question	Answer	Mark
1-1	We observe on the screen fringes that are straight, alternately bright and dark, parallel to each other and to the slits, and having the same dimensions.	½
1-2	We have the superposition of the two light beams emitted by S_1 and S_2. When these light beams reach a certain point in phase, we have a constructive interference and this point is the center of a bright fringe; when they reach another point in opposite phase, we have a destructive interference and this point is the center of a dark fringe.	½
1-3	The optical path difference at O is written as: $\delta = S_2O - S_1O = 0 \Rightarrow \delta = 0$. So, O is the center of a bright fringe since the waves received at O are in phase.	¾
1-4	The optical path difference is written as: $\delta = S_2M - S_1M = \frac{ax}{D}$	¼
1-5	For the centers of the dark fringes, we have: $\delta = \left(k + \frac{1}{2}\right)\lambda$ and $\delta = \frac{ax}{D}$ where $k \in \mathbf{Z}$. Thus: $x = \left(k + \frac{1}{2}\right)\frac{\lambda D}{a}$	½
1-6	The inter-fringe distance is the distance between the centers of two consecutive fringes of the same nature. $i = x_{k+1} - x_k = \left(k + 1 + \frac{1}{2}\right)\frac{\lambda D}{a} - \left(k + \frac{1}{2}\right)\frac{\lambda D}{a} = \frac{\lambda D}{a}$	**1**
1-7	$x = 3.75\text{ mm} = 3.75\times10^{-3}\text{ m}$ M is the center of a bright fringe if $\delta = k\lambda$, and M is the center of a dark fringe if $\delta = \left(k + \frac{1}{2}\right)\lambda$, k being an integer number. So: $\frac{\delta}{\lambda} = \frac{ax}{\lambda D} = 10^{-3} \times 3.75\times10^{-3} / (625\times10^{-9} \times 1) = 6$ So, M is the center of the 6^{th} bright fringe.	**1**
1-8	For the center of the central bright fringe, we have: $\delta = 0$; We get: $\frac{ax}{D} = e\,(n-1)$ and $i = \lambda D/a$, so: $i = 625\times10^{-9} \times 1/ 10^{-3} = 0.625\times10^{-3}\text{ m} = 0.625\text{ mm}$. but the abscissa x of the center of the second dark fringe is written as: $x = 3i/2 = 9.375\times10^{-4}\text{ m}$ We get: $e = \frac{ax}{D(n-1)} = \frac{9.375\times10^{-4} \times 10^{-3}}{1 \times (1.5-1)} = 1.875 \times 10^{-6}\text{ m}$	**1**
2-1	The width of the slit is: $b = 0.10\text{ mm} = 1.0\times10^{-4}\text{ m}$; it is very small. The light thus undergoes the diffraction phenomenon.	½
2-2	$L = \frac{2\lambda D}{b}$; so : $L = \frac{2\lambda D}{b} = \frac{2\times625\times10^{-9}\times1}{10^{-4}} = 1250\times10^{-5}\text{m} = 12.5\text{ mm}$	½
3	The first phenomenon is the phenomenon of light interference and the second is the phenomenon of light diffraction. So, it is the wave aspect of light.	½