المادة: الفيزياء الشهادة: الثانوية العامّة الفرع: العلوم العامة نموذج رقم 1 المدّة: ثلاث ساعات	الهيئة الأكاديميّة المشتركة قسم: العلوم	المركز التربوي للبحوث والإنماء

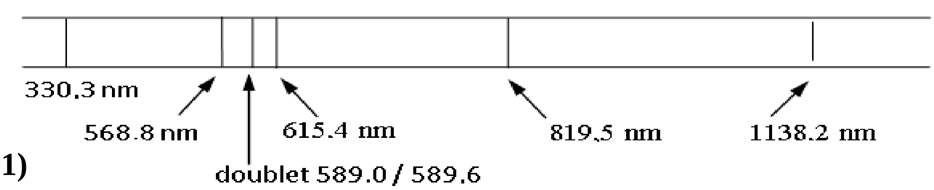
نموذج مسابقة (يراعي تعليق الدروس والتوصيف المعدّل للعام الدراسي 2016-2017 وحتى صدور المناهج المطوّرة)

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

Exercise 1 (6½ points) Sodium vapor lamp

Sodium vapor lamps are used for illuminating road tunnels. These lamps contain sodium vapor at very low pressure. This vapor is excited by an electron beam which passes inside the tube. Sodium atoms absorb the energy of electrons. This energy is restored when the atoms perform downward transition to the ground state in the form of light radiation.
Sodium vapor lamps mainly emit yellow light.
Given: $h=6.63\times10^{-34}$J.s; $c=3.00\times10^{8}ms^{-1}$; 1 eV= 1.60×10^{-19}J.

1) The analysis of the emission spectrum of a sodium-vapor lamp reveals the presence of spectral lines of well-defined wavelengths λ.

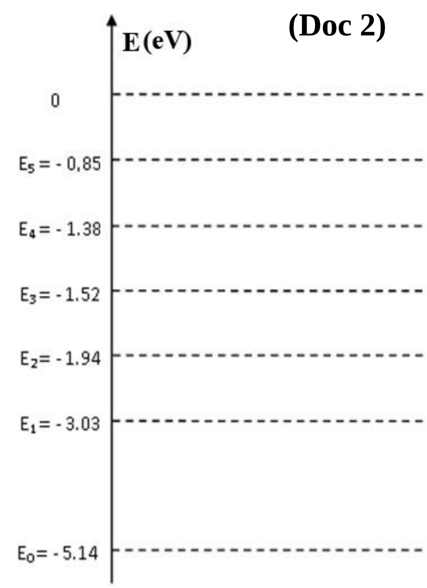


(Doc 1)

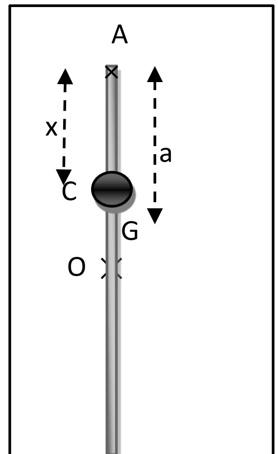
1-1) Identify the wavelengths belonging to the visible range, to the ultraviolet range, and to the infrared range.
1-2) Specify if the emission spectrum is a polychromatic or a monochromatic light.
1-3) The corresponding emission spectrum is discontinuous. Explain.
1-4) Calculate the energy, in (eV), of the spectral line of wavelength λ = 589.0 nm.

2) The diagram of energy levels of the sodium atom is given in the adjacent document (Doc 2).
2-1) Calculate, in joule, the energy (E_0) of the atom when it is in the ground state.
2-2) Determine the minimum energy needed to excite the sodium atom from its ground state.
2-3) The sodium atom being in the third excited state:
2-3-1) Determine the minimum energy needed to ionize it;
2-3-2) Determine the wavelength of the radiation emitted due to the de-excitation to the energy level E_1= -3.03 eV.
2-4) The sodium atom, now considered in the first excited state E_1, receives a radiation of energy E = 1.09 eV. Specify if this radiation can interact with the sodium atom.
2-5) The sodium atom is in the ground state.
2-5-1) It absorbs a photon which is associated to a radiation of wavelength λ = 289.77 nm. Determine the state of the atom.
2-5-2) It absorbs a photon of energy 6 eV. An electron is thus liberated by the atom. Calculate, in eV, the kinetic energy of that electron.

(Doc 2)



Exercise 2 (7 points) Compound Pendulum



(Doc 3)

In order to determine the proper period of a given compound pendulum, the following two procedures are done separately as shown in parts **1)** and **2)**.

The compound pendulum is formed of a rod AB of length AB = L = 1 m and of mass M = 1.2 kg and a particle "m" of mass m = 500 g which can slide between A and O. "m" is fixed at point C such that AC = x. The pendulum can rotate in the vertical plane around a horizontal axis (Δ) passing through A. Let a = AG be the distance between A and the center of gravity G of the pendulum. (Doc 3)
The pendulum is shifted by an angle $\theta_o = 8^o$ from its equilibrium position, in the positive direction, and then released from rest at the instant $t_0 = 0$. Let θ and θ' be respectively the angular abscissa and the angular velocity of the pendulum at an instant t.
Take: The horizontal plane containing A as the gravitational potential energy reference.

$g = 10\ m/s^2$; for $\theta < 10°$, $\sin\theta \approx \theta_{rd}$ and $\cos\theta \approx 1 - \frac{\theta_{rd}^2}{2}$.

Neglect all resistive forces.

1) Determination of the expression of T_0 in terms of x

1-1) Show that the position of the center of gravity G of the system is given by the relation: $AG = a = \frac{2mx + ML}{2(m + M)}$

1-2) Show that the moment of inertia I of the pendulum with respect to (Δ) is: $I = (3mx^2 + ML^2)/3$, knowing that the moment of inertia of the rod with respect to the axis (Δ) is: $I_{rod} = ML^2/3$.

1-3) Determine the expression of the mechanical energy of the system (pendulum, Earth) in terms of m, M, g, a, I, θ and θ'.

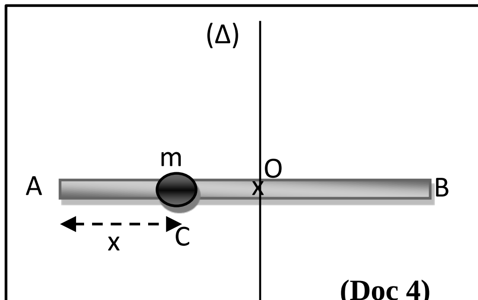
1-4) Derive the differential equation in θ that governs the motion of the pendulum.

1-5) The solution of the differential equation is $\theta = \theta_m \cos(\omega_o t + \varphi)$ where θ is in rd and t in sec. Determine θ_m and φ.

1-6) Determine the expression of the proper period T_0 in terms of x.

2) Determination of x

Now the system (rod AB & particle) is placed horizontally; it can rotate freely around the vertical axis (Δ) that passes through the midpoint O. The particle is fixed at the end C of a string OC (Doc 4). The system rotates with a constant angular speed of 2 rd/sec when the particle of mass m is at point C (AC = x). At a certain instant, the string is cut and the particle of mass m slides and sticks at the extremity A of the rod; the angular speed of the system becomes 1.5 rd/sec.



(Doc 4)

2-1) If I_1 is the moment of inertia of the system (rod AB & mass m) when m is at the point C and I_2 the moment of inertia of this system when m is at the extremity A, verify that:
$I_1 = 0.1 + 0.5(0.5-x)^2$ and $I_2 = 0.225\ kg.m^2$ knowing that the moment of inertia of the rod around the axis (Δ) passing through its center is $I_{rod/\Delta} = ML^2/12$.

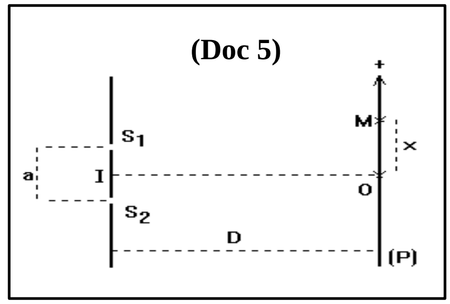
2-2) Apply the principle of conservation of angular momentum to determine x.

2-3) Using the results of parts **1)** and **2)**, deduce the value of the proper period T_o.

Exercise 3 (6½ points) Aspect of light

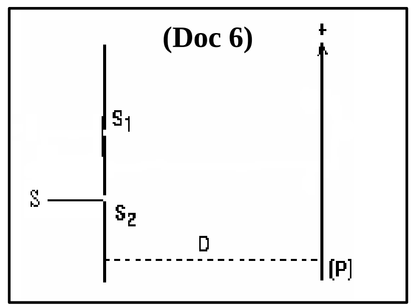
1) In a Young's set up in air, the two slits S_1 and S_2 that are straight, parallel and separated by a distance a = 1 mm, are illuminated by the same source S that is equidistant from S_1 and S_2, S emitting a monochromatic light of wavelength λ= 625 nm.

The screen of observation (P), parallel to the plane of S_1S_2, is found at a distance D = 1 m from the point I, the mid-point of S_1S_2. We consider a point M in the zone of interference on (P) whose position is defined by its abscissa x relative to the point O, the orthogonal projection of I on (P). (Doc 5).



1-1) Specify the nature of the fringe whose center is at O.
1-2) Describe the fringes observed on the screen (P).
1-3) Interpret the existence of fringes.
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, a and λ.
1-6) Deduce the inter-fringe distance in terms of λ, D and a.
1-7) Determine the type and order of the fringe at a point M on the screen whose distance from the center of the central fringe is 3.75 mm.
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 M becomes: $S_2M - S_1M = \delta = ax/D - e(n-1)$.
The center of the central fringe occupies now a position that was occupied previously by the center of the 6th dark fringe. Determine e.

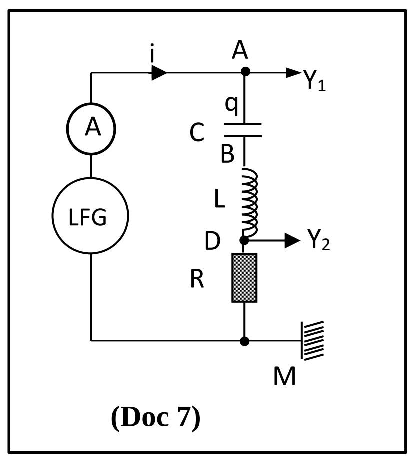
2) Now we cover the slit S_1 and the source S emitting the monochromatic radiation, is placed facing the slit S_2 whose width is 0.1 mm (Doc 6).



2-1) Name the phenomenon that the light undergoes through the slit.
2-2) Let L be the width of the central fringe observed on the screen:
2-2-1) Give the expression of L;
2-2-2) Calculate L.
2-3) The preceding two optical phenomena show evidence of a particular aspect of light. Identify this aspect.

Exercise 4 (7½ points) Determination of the characteristics of electric components

The aim of this exercise is to determine the characteristics R, L and C of a resistor of adjustable resistance R, a coil of inductance L and of negligible resistance and a capacitor of capacitance C respectively.
For this, we perform the following two experiments:



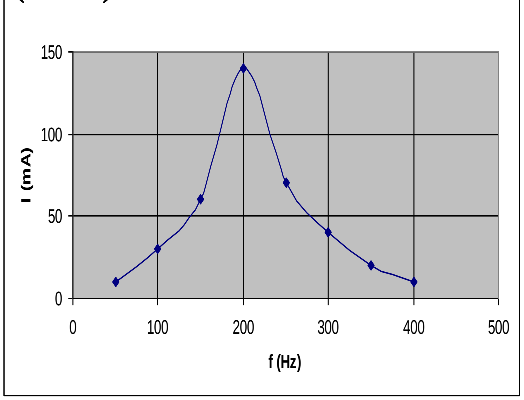
1) 1st experiment:

Consider a series circuit (Doc 7) that consists of an LFG which delivers across its terminals an alternating sinusoidal voltage of effective value U and of adjustable frequency f,
a pure resistor of resistance R, a coil of inductance L and of negligible resistance, a capacitor of capacitance C and an ammeter.

We give f different values and we register, for each value of f, the effective current I in the circuit. We obtain the graph plotted in (Doc 8) which gives I as a function of f.

Take $\pi^2 = 10$.

(Doc 8)



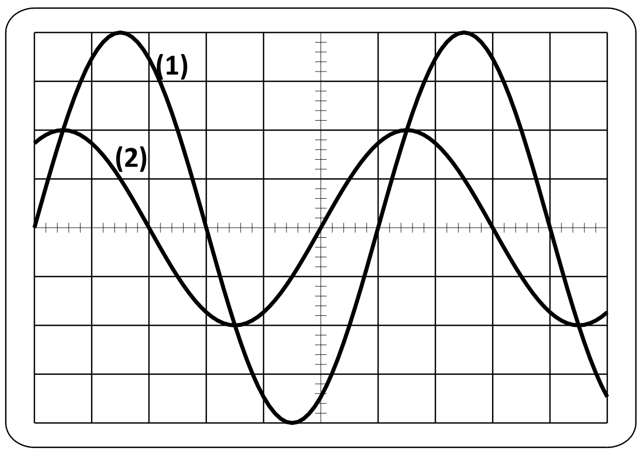
1-1) The circuit is the seat of a certain phenomenon. Name the physical phenomenon that takes place for f = 200 Hz. Justify

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

1-3) Show that $LC = 0.625 \times 10^{-6}\ s^2$.

2) 2nd experiment:

We give R the value 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 as shown to display the voltage u_{AM} across the LFG and the voltage u_{DM} across the resistor. (Doc 9) shows the waveform (1) corresponding to the voltage u_{AM} and the waveform (2) that corresponds to the voltage u_{DM}.
The frequency of u_{AM} is adjusted to f = 50 Hz.
The vertical sensitivity on both channels is 5 V/division.
Take $\pi^2 = 10$.



(Doc 9)

2-1) Referring to the waveforms:
2-1-1) Calculate the maximum value U_m of u_{AM};
2-1-2) Determine, as a function of time t, the expression of the voltage u_{DM};
2-1-3) Deduce the expression of i.
2-2)
2-2-1) Determine the expression of the voltage u_{AB} across the terminals of the capacitor.
2-2-2) Determine the expression of the voltage u_{BD} across the terminals of the coil.
2-2-3) Using the relation $u_{AM} = u_{AB} + u_{BD} + u_{DM}$ and giving t the value zero, show that the second relation between L and C is:

$$3.3\pi^2 LC + 5\pi\sqrt{3}C = 3.3\times10^{-4}$$

2-3) Conclusion:
Determine the values of L and C from the above two relations obtained between L and C.

الهيئة الأكاديميّة المشتركة قسم: العلوم	المادة: الفيزياء الشهادة: الثانوية العامّة الفرع: العلوم العامة نموذج رقم 1 المدّة: ثلاث ساعات

المركز التربوي للبحوث والإنماء

أسس التصحيح (تراعي تعليق الدروس والتوصيف المعدّل للعام الدراسي 2016-2017 وحتى صدور المناهج المطوّرة)

Exercise 1 (6½ points) Sodium vapor lamp

Question	Answer	Mark
1-1	Visible range (400 nm < λ < 800 nm): 568.8 nm, 589.0 nm, 589.6 nm and 615.4 nm. Ultraviolet range (λ < 400 nm): 330.3 nm. Infrared range (λ > 800 nm): 819.5 nm and 1138.2 nm	 ¼ ¼ ¼
1-2	Polychromatic since the emitted spectrum is formed of many radiations of different wavelengths.	¼
1-3	The energy of the atom cannot take any value; it takes only some discrete and particular values. The energy of the atom is quantized.	½
1-4	$E = hc/\lambda = 3.372\times10^{-19}$ J = 2.11 eV	½
2-1	$E = -5.14$ eV $= -10.8\times10^{-19}$ J	¼
2-2	It corresponds to an upward transition from the energy level E_0 to the energy level E_1. $E_{\text{min to excite the atom}} = E_1 - E_0 = -3.03 + 5.14 = 2.11$ eV	½
2-3-1	It is an upward transition from the energy level E_3 to the ionized state $E_\infty = 0$. $E_{ioniz} = E_\infty - E_3 = 1.52$ eV	½
2-3-2	$E = E_3 - E_1 = -1.52 + 3.03 = 1.51$ eV $= 2.4\times10^{-19}$J $\lambda = hc/E = 6.62\times10^{-34} \times 3\times10^8/2.4\times10^{-19} = 827.5$ nm	¾
2-4	The energy is absorbed and the atom become in the state E_2 since $-3.03 + 1.09 = -1.94$ eV $= E_2$ (second excited state)	1
2-5-1	$E_{photon} = hc/\lambda = 6.62\times10^{-34} \times 3\times10^8/289.77\times10^{-9} = 6.86\times10^{-19}$ J = 4.29 eV $E_0 + E_{photon} = -5.14 + 4.29 = -0.85$ eV $= E_5$, the atom, in its ground state, absorbs the energy of the photon and becomes in the fifth excited state	½ ½
2-5-2	$KE = E_0 + 6$; $KE = 6 - 5.14 = 0.86$ eV	½

Exercise 2 (7 points) Compound Pendulum

Question	Answer	Mark
1-1	$(M + m)\overrightarrow{AG} = M\overrightarrow{AO} + m\overrightarrow{AC}$. All the vectors have the same direction: $(M+m)AG = M\,AO + m\,AC$. $(M + m)a = M\,L/2 + m\,x$. $AG = a = \frac{mx+ML/2}{(m+M)} = \frac{2mx+ML}{2(m+M)}$	½
1-2	$I = I_{rod} + mx^2 = ML^2/3 + mx^2 = (ML^2 + 3mx^2)/3$	½
1-3	$ME = KE + PE_p = ½\, I\, \theta'^2 - (m + M)g.a.\cos\theta$	½
1-4	ME = constant $\Rightarrow$ $dME/dt = 0$; $I.\theta'.\theta'' + (m + M).g.a.\theta'.\sin\theta = 0$; $\sin\theta = \theta$ (for small angles); $\theta' \neq 0$; $\theta'' + \frac{(m+M).g.a}{I}.\theta = 0$	1

1-5	$\theta = \theta_m \cos(\omega_o t + \varphi)$; $\theta' = -\theta_m \omega_0 \sin(\omega_o t + \varphi)$; At t=0; $0 = -\theta_m \omega_0 \sin(\varphi)$; $\varphi = 0$ or $\varphi = \pi$ rd $\theta_o = \theta_m \cos\varphi > 0$ so $\varphi = 0$ accepted; replace for $\varphi = 0$ to get $\theta_m = 8\pi/180 = 0.14$ rd so: $\theta = 0.14 \cos(\omega_o t)$	1
1-6	$T_0 = 2\pi/\omega_0 = 2\pi\sqrt{I/(M+m)ga} = 2\pi\sqrt{(3x^2 + 2.4)/[30(1.2 + x)]}$	½
2-1	$I_1 = I_{rod} + m \times OC^2 = ML^2/12 + m(L/2 - x)^2 = 0.1 + 0.5\,(0.5 - x)^2$. $I_2 = ML^2/12 + m(L/2)^2 = 0.225$ kgm^2	½ ½
2-2	Forces acting are: $m\vec{g}$; $M\vec{g}$; reaction of the axis $\vec{R}$; The sum of the moments of these forces with respect to the axis (Δ) is zero $\sum M = 0$; so angular momentum is conserved. Then $\sigma_i = \sigma_f$ $I_1\theta'_1 = I_2\theta'_2$ $[0.1 + 0.5\,(0.5 - x)^2] \times 2 = [0.225] \times 1.5$ x = 0.13 m or x = 0.87 > 0.5 rejected	½ ½ ½
2-3	substitute x =0.13 m in $T_0 = 2\pi\sqrt{(3x^2 + 2{,}4)/[30(1{,}2 + x)]}$ to get T_0 = 1.56 sec.	½

Exercise 3 (6½ points) Aspect of light

Question	Answer	Mark
1-1	We observe on the screen at O a bright fringe since S_1 and S_2 are in phase, so the light issued from S_1 and that issued from S_2 reach O in phase because $S_1O = S_2O$ $\Rightarrow$ $\delta = 0$. (k = 0).	½
1-2	Straight , parallel, equidistant and alternating bright and dark fringes	½
1-3	The superposition of the two light beams emitted by the sources S_1 and S_2 gives rise to an interference phenomenon	¾
1-4	$\delta = \frac{ax}{D}$	¼
1-5	For the center of the dark fringes, we have $\delta = (2k+1)\lambda/2$. We get $\frac{ax}{D} = (2k+1)\lambda/2$, so $x = (2k+1)\frac{\lambda D}{2a}$	½
1-6	The inter-fringe distance is the distance between the centers of two consecutive fringes of same nature. $i = x_{k+1} - x_k = \frac{(2k+3)\lambda D}{2a} - \frac{(2k+1)\lambda D}{2a} = \frac{\lambda D}{a}$	½ ½
1-7	x = 3.75 mm = 3.75×10^{-3} m $\delta = \frac{ax}{D} = (10^{-3} \times 3.75\times10^{-3})/1 = 3.75\times10^{-6}$ m. $\frac{\delta}{\lambda} = (3.75\times10^{-6})/(0.625\times10^{-6}) = 6$ So $\delta = 6\lambda = k\,\lambda$ et k appartient à Z M is the center of a bright fringe of the 6th order.	½ ½

1-8	In the central fringe, we have $\delta = 0$. $\frac{ax}{D} = e(n-1)$ but $x = 5.5i = 5.5\frac{\lambda D}{a}$ $\Rightarrow$ $\frac{a}{D}.\frac{5.5\times\lambda D}{a} = e(n-1)$ $\Rightarrow$ $5.5\times\lambda = e(n-1)$ $e = \frac{5.5\times\lambda}{(n-1)}$ $e = 6.9\times10^{-6}$ m	½
2-1	The light undergoes the phenomenon of diffraction.	½
2-2-1	$L = \frac{2\lambda D}{a}$	¼
2-2-2	$L = \frac{2\times625\times10^{-9}\times1}{0.1\times10^{-3}} = 0.0125\,\text{m} = 12.5\,\text{mm}$	¼
2-3	It is the wave aspect of light.	½

Exercise 4 (7½ points) Determination of the characteristics of electric components

Question	Answer	Mark
1-1	Current resonance phenomenon because I takes a maximum value.	½
1-2	$f_0 = 200$ Hz	½
1-4	$f_0 = \frac{1}{2\pi\sqrt{LC}}$ $LC = 0.625\times10^{-6}$ s^2 (equation 1)	½
2-1-1	$U_m = S_v \times y = 20\,V$	½
2-1-2	The waveform displayed on channel Y_2 leads that displayed on channel Y_1 since the voltage u_{DM} takes the maximum value before the voltage u_{AM}, both varying in the same sense. One period extends over D = six divisions and the phase difference corresponds to d = one division, so: $\phi = 2\pi\left(\frac{d}{D}\right) = 2\pi\left(\frac{1}{6}\right) = \frac{\pi}{3}$rd $\omega_0 = 2\pi f = 100\pi$ rd/s $U_{m2} = S_v \times y_2 = 10$ V $u_{DM} = 10 \sin(100\pi t + \pi/3)$ (u_{DM} in V, t in s)	½ ½ ½
2-1-3	$i = \frac{u_{DM}}{R} = \frac{10}{150}\sin(100\pi t + \frac{\pi}{3})$ $\Rightarrow$ $i = 0.067\sin(100\pi t + \frac{\pi}{3})$ (i in A, t in s)	½
2-2-1	$u_{AB} = u_C = \frac{1}{C}\int i\,dt = -\frac{0,067}{100\pi C}\cos(100\pi t + \frac{\pi}{3})$	¾
2-2-2	$u_L = L\frac{di}{dt} = 6.7\,\pi L\,\cos(100\pi t + \frac{\pi}{3})$	¾

2-2-3	$u_{AM} = u_{AB} + u_{BD} + u_{DM}$ $20\sin(100\pi t) =$ $-\frac{0.067}{100\pi C}\cos(100\pi t + \frac{\pi}{3}) + 6.7\pi L\ \cos(100\pi t + \frac{\pi}{3}) + 10\sin(100\pi t + \frac{\pi}{3})$ For t = 0 $0 = -\frac{0.067}{100\pi C}\cos(\frac{\pi}{3}) + 6.7\pi L\ \cos(\frac{\pi}{3}) + 10\sin(\frac{\pi}{3})$ $0 = -\frac{0.067}{200\pi C} + 3.3\pi L + 10\frac{\sqrt{3}}{2}$ we get: $\Rightarrow$ $3.3\pi^2 LC + 5\pi\sqrt{3}C = 3.3\times 10^{-4}$ (equation 2)	1
2-3	Substitute equation (1) in equation (2) we get: $\begin{cases} C = 1.13\times 10^{-5}F = 0.113\mu F \\ L = 0.054\,H = 54\ mH \end{cases}$	1