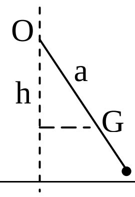
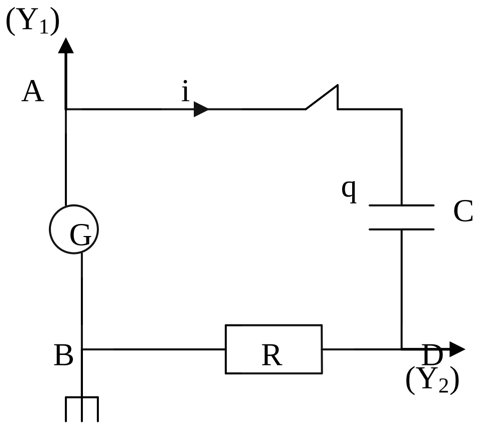
First exercise (7.5 points)

Part of the Q	Answer	Mark
A.1.a	ΣM = M(weight) + M(reaction of the axis) + M The weight & the reaction meet the axis of rotation: $\Sigma M = 0 + 0 + M = M$	0.75
A.1.b	$\frac{d\sigma}{dt} = \Sigma M = M = I_0 \cdot \theta'' = cte \Rightarrow \theta'' = cte$, initial speed being null $\Rightarrow$ the rotational motion of the rod is uniformly accelerated.	0.5
A.1.c	$\theta'' = cte = \frac{M}{I_0} \Rightarrow \theta' = \frac{M\,t}{I_0}$. $\sigma = I_0\theta' = M\,t$	0.5
A.2	$\theta' = 2\pi N \Rightarrow$ At t_1: $2\pi N I_0 = M t_1 \Rightarrow I_0 = \frac{0.1\times10}{2\pi\times8} = 1.99\times10^{-2} \approx 0.02$ kg.m^2	1
B.1.a	$a = \frac{m\times0 + m'\frac{\ell}{2}}{(m+m')} = \frac{m'\ell}{2(m+m')}$.	0.5
B.1.b	$I = I_0 + m'\frac{\ell^2}{4}$	0. 5
B.2	$ME = KE + PE_g = ½\, I(\theta')^2 - (m + m')g\,h$ $h = a\cos\theta \Rightarrow ME = ½ I(\theta')^2 - (m + m')g\,a\cos\theta$.  	1
B.3.a	$\frac{dME}{dt} = 0 = I\theta''\theta' + (m + m')g\,a\,\theta'\sin\theta$. θ is small, $\sin\theta \approx \theta \Rightarrow \theta'' + \frac{(m+m')ga}{I}\theta = 0$.	1
B.3.b	The differential equation characterizes a simple harmonic motion of angular frequency $\omega = \sqrt{\frac{(m+m')ga}{I}}$. The expression of the proper period is: $T = 2\pi\sqrt{\frac{I}{(m+m')ga}} = 2\pi\sqrt{\frac{I_0 + m'\frac{\ell^2}{4}}{(m+m')g\frac{m'\ell}{2(m+m')}}}$ $T = 2\pi\sqrt{\frac{I_0 + m'\frac{\ell^2}{4}}{g\frac{m'\ell}{2}}} = \sqrt{\frac{8I_0 + 2m'\ell^2}{m'\ell}}$.	1
B.4	$T = 1.732$ s $= \sqrt{3}$ s $\Rightarrow 3 = \frac{8I_0 + 0.32}{0.16} \Rightarrow I_0 = \frac{0.16}{8} = 0.02$ kg.m^2.	0.75

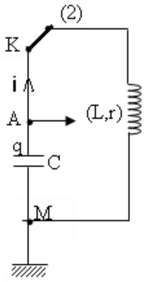
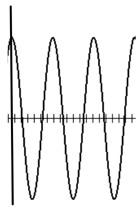
Second exercise (7.5 points)

Part of the Q	Answer	Mark
A.1.a	$i = \frac{dq}{dt} \Rightarrow i = C\frac{du_C}{dt}$.	0.5
A.1.b	$u_C = \frac{1}{C}\int idt \Rightarrow u_C = -\frac{I\sqrt{2}}{C\omega}\cos(\omega t+\varphi)$.	0.5
A.1.c	$U_C = \frac{I}{C\omega}$	0.25
A.2	$U\sqrt{2}\sin\omega t = RI\sqrt{2}\sin(\omega t+\varphi) - \frac{I\sqrt{2}}{C\omega}\cos(\omega t+\varphi)$ For $t_0 = 0 \Rightarrow 0 = RI\sqrt{2}\sin\varphi - \frac{I\sqrt{2}}{C\omega}\cos\varphi \Rightarrow \tan\varphi = \frac{1}{RC\omega}$.	1.25
B.1.a	Connections of the oscilloscope  Fig 1	0.5
B.1.b.i	$T \to 6$ ms $\Rightarrow f = 166.67$ Hz	0.5
B.1.b.ii	(a) leads (b)	0.5
B.1.b.iii	In the (RC) circuit, the current (or u_R) leads the voltage u_G , thus (a) displays the voltage u_{DB}.	0.5
B.1.b.iv	$\lvert\varphi\rvert = \frac{2\pi\times 1}{6} = \frac{\pi}{3}$ rad.	0.5
B.1.c	$tg\varphi = \frac{1}{RC\omega} = \sqrt{3}$ $\Rightarrow \mathbf{C} = \frac{1}{250\times\sqrt{3}\times 166.67\times 2\pi} = 2.2\times10^{-6}$ F = 2.2 μF	1.25
B.2	$U_R = RI$ and $U_C = \frac{I}{C\omega} \Rightarrow \frac{U_C}{U_R} = \frac{1}{RC\omega}$ $\Rightarrow C = \frac{2.2}{3.2\times 250\times 2\pi\times 200} = 2.19\times10^{-6}$ F = 2.2 μF	1.25

Third exercise (7.5 points)

Part of the Q	Answer	Mark
I – A.1	Diffraction	0.25
I – A.2	$\tan\theta_1 = \frac{x/2}{D} = \frac{x}{2D} = 0.02 \approx \sin\theta_1 = \theta_1$ But for the 1st dark fringe: $\sin\theta_1 = \frac{\lambda}{a}$ then $a = \frac{\lambda}{0.02}$ but $\lambda = \frac{c}{\upsilon} = \frac{3\times10^8}{6.163\times10^{14}}$ =0.4868 μm thus a = 24 μm	1.25
I – B	Alternate bright – dark fringes , rectilinear, parallel to each other and to the slits and equidistant The interfringe $i = \frac{\lambda D}{a}$, in mm we get i = 0.4868×2 = 0.97mm≈ 1mm.	1.25
I – C	Wave aspect of light.	0.25
II – A.1.a	$W_0 = h\nu_o$ thus the threshold frequency is $\nu_o = \frac{W_0}{h} = 4.568\times10^{14}$ Hz	0. 5
II – A.1.b	$\nu > \nu_o$ thus there is emission of electrons	0.25
II – A.2	Maximum kinetic energy $KE_m = h\nu - W_0$ $KE_m = (6.163\times10^{14}\times6.62\times10^{-34})-(1.89\times1.6\times10^{-19}) = 1.056\times10^{-19}$J	0.75
II – B.1	$h\nu = \frac{(6.163\times10^{14}\times6.62\times10^{-34}}{(1.6\times10^{-19})} = 2.55$eV. If the photon is absorbed, we obtain: –13.6 + 2.55= –11.05 eV. This level does not exist. This photon is not absorbed.	1
II – B.2.a	– 3.4 + 2.55 = - 0.85eV which matches the level n = 4	0.5
II – B.2.b	- The visible radiations correspond to Balmer series - The two possible transitions :4 $\rightarrow 2$ or $3 \rightarrow 2$ - λ (max) corresponds to $\Delta E = (E_n - E_2)_{min}$ $\Rightarrow$ Transition $3 \rightarrow 2$	1.25
II – C	The corpuscular aspect of light.	0.25

Fourth exercise (7.5 points)

Part of the Q	Answer	Mark
A.1	At the end of the charging, $u_{AM} = E = U_0 = 3$ V.	0.50
A.2	$W_0 = ½ CE^2 = 4{,}5\times10^{-6}$ J.	0.50
B.1.a	Arbitrary direction for i 	0.50
B.1.b	$u_C = ri + L\frac{di}{dt}$, $i = -\frac{dq}{dt} = -C\frac{du_C}{dt}$ => $\mathbf{u_C} = -LC\ u''_C => LC\ u''_C + u_C\ \mathbf{= 0 =>}\ u''_C + \frac{1}{LC}\ \mathbf{u_C = 0.}$	1.5
B.1.c	$\omega_0^2 = \frac{1}{LC} => T_0 = 2\pi\sqrt{LC} = 1.99$ ms.	1
B.1.d		0.50
B.1.e	The free oscillations are undamped.	0.25
B.2.a	The free oscillations are damped.	0.25
B.2.b	The total energy in the circuit is not constant because of resistance of the coil which dissipates energy in the form of heat.	0.50
B.2.c.i	$T = \frac{10}{5} = 2$ ms	0.25
B.2.c.ii	$T > T_0$	0.25
B.2.c.iii	Around 0.	0.25
B.3.a	Around E = 3 V.	0.25
B.3.b	T = 2 ms.	0.25
B.3.c,i	For $0{,}5\text{ ms} \le t \le 1\text{ ms}$ u_C increases and i decreases $\Rightarrow$ the coil gives energy to the capacitor.	0.25
B.3.c.ii	For $1\text{ms} \le t \le 1.5\text{ ms}$: u_C decreases and i increases $\Rightarrow$ the capacitor gives energy to the coil.	0.25
B.3.c.iii	For $0 \le t \le 0.5\text{ ms}$: u_C increase and i increases $\Rightarrow$ no exchange of energy between the coil and the capacitor.	0.25

الدورة العادية للعام 2011	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	

<u>This exam is formed of four exercises in four pages</u>
<u>The use of non-programmable calculator is recommended</u>

<u>First Exercise</u> *(7.5 points)* ***<u>Moment of inertia of a rod</u>***

Consider a homogeneous and rigid rod AB of negligible cross-section, of length ℓ = 1 m and of mass m = 240 g. This rod may rotate about a horizontal axis (Δ) perpendicular to it through its midpoint O.
The object of this exercise is to determine, by two methods, the moment of inertia I_0 of the rod about the axis (Δ).The vertical position CD of the rod is considered as an origin of angular abscissa. Neglect all friction.

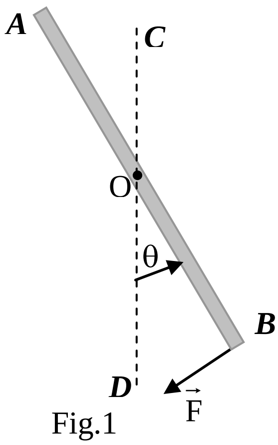


Fig.1

Take: g = 10 m/s^2; $\pi^2 = 10$; $\sqrt{3} = 1.732$; $\sin\theta \approx \theta$ and $\cos\theta \approx 1 - \frac{\theta^2}{2}$ for small angles θ measured in radians.

A – <u>First method</u>

The rod, starting from rest at the instant t_0 = 0, rotates around (Δ) under the action of a force $\vec{F}$ whose moment about (Δ) is constant of magnitude $\mathbf{M}$ = 0.1 m.N (Fig.1).
At an instant t, the angular abscissa of the rod is θ and its angular velocity is θ'.

1) ***a)*** Show that the resultant moment of the forces acting on the rod about (Δ) is equal to $\mathbf{M}$.
b) Determine, using the theorem of angular momentum, the nature of the motion of the rod between t_0 and t.
c) Deduce the expression of the angular momentum σ of the rod, about (Δ), as a function of time t.

2) Determine the value of I_0, knowing that at the instant t_1 = 10 s, the rotational speed of the rod is 8 turns/s.

B – <u>Second method</u>

We fix, at point B, a particle of mass m' = 160 g. The system (S) thus formed constitutes a compound pendulum whose center of mass is G. (S) may oscillate freely, about the axis (Δ).
We shift (S), from its stable equilibrium position, by a small angle and we release it without velocity at the instant t_0 = 0.
At an instant t, the angular abscissa of the pendulum is θ and its angular velocity is $\theta' = \frac{d\theta}{dt}$.
The horizontal plane through O is taken as a gravitational potential energy reference.

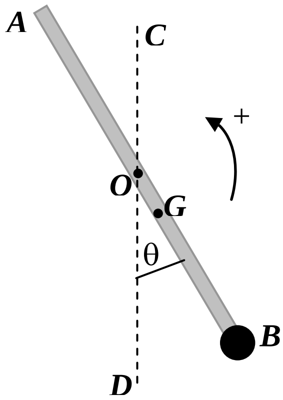


Fig.2

1) Determine:
a) The position of G relative to O (a = OG), in terms of m, m' and ℓ;
b) The moment of inertia I of (S) about (Δ), in terms of I_0, m' and ℓ.

2) Determine, at the instant t, the mechanical energy of the system [(S), Earth], in terms of I, θ', θ, m, m', a and g.

3) ***a)*** Derive the second order differential equation that describes the motion of (S).
b) Deduce the expression of the proper period T of the oscillations of (S), in terms of I_0, m', ℓ and g.

4) The duration of 10 oscillations of the pendulum is 17.32 s.
Determine the value of I_0.

Second exercise *(7.5 points)* ***Determination of the capacitance of a capacitor***

In order to determine the capacitance C of a capacitor, we consider the following components:

- A generator G delivering across its terminals an alternating sinusoidal voltage of effective value U and of adjustable frequency f;
- A resistor of resistance R = 250 Ω;
- An oscilloscope;
- Two voltmeters V_1 and V_2;
- A switch;
- Connecting wires.

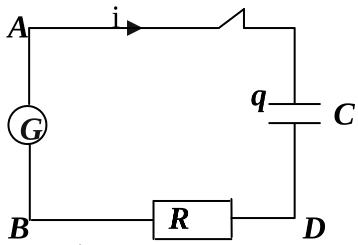


Fig 1

We connect up the circuit whose diagram is represented in figure 1.

A – Theoretical study

The voltage across the generator is $u_{AB} = U\sqrt{2}\sin\omega t$. In the steady state, the current i carried by the circuit has the form: $i = I\sqrt{2}\sin(\omega t + \varphi)$, where I is the effective value of i.

1) ***a)*** Give the expression of the current i in terms of C and $\frac{du_C}{dt}$ with $u_C = u_{AD}$.

b) Determine the expression of the voltage u_C in terms of I, C, ω and t.

c) Deduce the expression of effective value U_C of u_C in terms of I, C and ω.

2) Applying the law of addition of voltages and giving t a particular value, show that $\tan\varphi = \frac{1}{RC\omega}$.

B – Determination of C

1) Using the oscilloscope

The oscilloscope, conveniently connected, displays on channel (Y_1) the voltage u_{AB} across the generator and on channel (Y_2) the voltage u_{DB} across the resistor. On the screen of the oscilloscope, we obtain the waveforms represented in figure 2.

Time base [horizontal sensitivity]: 1 ms / div.

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

b) Referring to figure 2,

i) determine the frequency of u_{AB};

ii) which of the waveforms, (a) or (b), leads the other?

iii) the waveform (a) displays u_{DB}. Why?

iv) determine the phase difference between the voltages u_{AB} and u_{DB}.

c) Calculate the value of C.

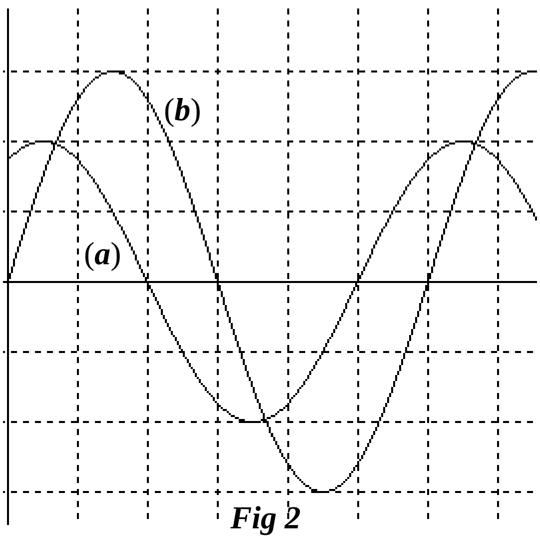


Fig 2

2) Using the voltmeters

The oscilloscope is removed and the frequency f is adjusted to the value 200 Hz. We then connect V_1 across the resistor and V_2 across the capacitor. V_1 and V_2 reads then the values 2.20 V and 3.20 V respectively.

Using these obtained measured values and the results of part A, determine the value of C.

Third Exercise *(7.5 points)* ***Aspects of light***

Consider a source (S) emitting a monochromatic luminous visible radiation of frequency $\nu = 6.163\times10^{14}$ Hz.

Given: $c = 3\times10^{8}$ m/s ; $h = 6.62\times10^{-34}$ J·s ; 1eV = 1.6×10^{-19} J.

I – First aspect of light

A – This source illuminates a very thin slit that is at a distance of 10 m from a screen. A pattern, extending over a large width, is observed on the screen.

1) Due to what phenomenon is the formation of this pattern?

2) Determine the width of the slit knowing that the linear width of the central fringe is 40cm.

B – The same source illuminates now the two slits of Young's double slit apparatus, these slits are vertical and are separated by a distance a = 1 mm. A pattern is observed on a screen placed parallel to the plane of the slits at a distance D = 2 m from this plane.

Describe the observed pattern and calculate the interfringe distance i.

C – What aspect of light do the two preceding experiments show evidence of ?

II – Second aspect of light

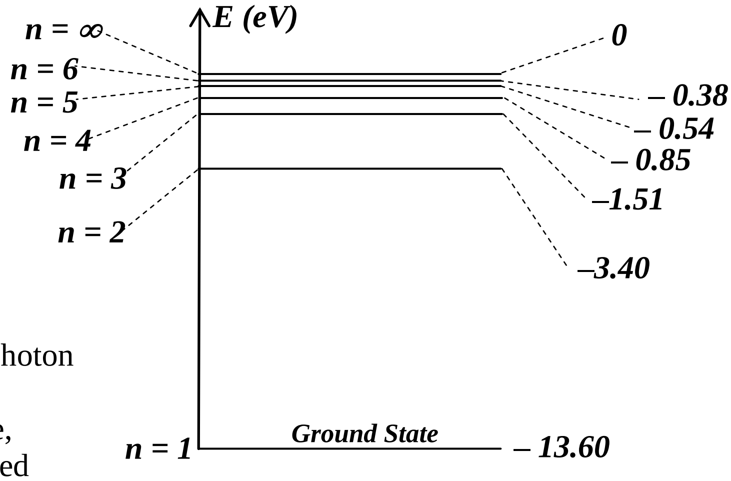
A – A luminous beam emitted by (S) falls on a cesium plate whose extraction energy is W_0 = 1.89 eV.

1) ***a)*** Calculate the threshold frequency of cesium.

b) Deduce that the plate will emit electrons.

2) Determine the maximum kinetic energy of an emitted electron.

B – The adjacent figure represents the energy diagram of a hydrogen atom.



The energy of the hydrogen atom is given by

$$E_n = \frac{-13.6}{n^2}$$

(E_n is in eV and n is a non-zero positive integer).

1) A hydrogen atom, in its ground state, receives a photon from (S). This photon is not absorbed. Why?

2) The hydrogen atom, found in its first excited state, receives a photon from (S). This photon is absorbed and the atom thus passes to a new excited state.

a) Determine this new excited state.

b) The atom undergoes a downward transition. Specify the transition that may result in the emission of the visible radiation whose wavelength is the largest.

C – What aspect of light do the parts A and B show evidence of ?

Fourth Exercise *(7.5 points)* ***Electromagnetic Oscillations***

The object of this exercise is to show evidence of the phenomenon of electromagnetic oscillations in different situations.

For this purpose, we consider an ideal generator G of e.m.f E = 3 V, an uncharged capacitor of capacitance C =1μF, a coil of inductance L= 0.1 H and of resistance r, a resistor of resistance R, an oscilloscope, a double switch K and connecting wires.

A – Charging of a capacitor

We connect up the circuit whose diagram is represented in figure1.

The oscilloscope is connected across the capacitor.

The switch K is in position (1). The capacitor is totally charged and the voltage across it is then $u_{AM} = U_0$.

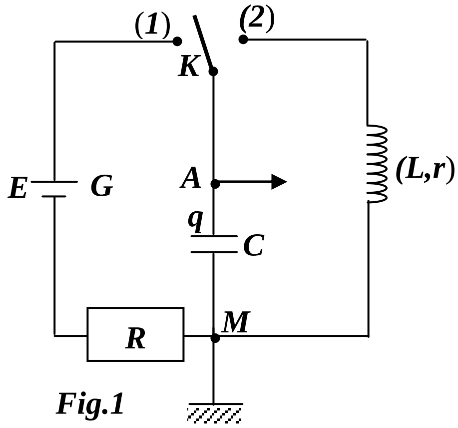


Fig.1

1) Determine the value of U_0.

2) Calculate the electric energy W_0 stored in the capacitor at the end of charging.

B – Electromagnetic oscillations

The capacitor being totally charged, we turn the switch K to position (2) at the instant $t_0 = 0$.The circuit is then the seat of electromagnetic oscillations. At an instant t, the circuit carries a current i.

1) ***First situation (ideal circuit)*** In the ideal circuit, we neglect the resistance r of the coil.
   - ***a)*** Redraw figure 1 showing on it an arbitrary direction of i.
   - ***b)*** Derive the differential equation that governs the variation of the voltage $u_{AM} = u_C$ across the capacitor as a function of time.
   - ***c)*** Deduce, then, the expression of the proper period T_0 of the electric oscillations in terms of L and C and calculate its value in ms with 2 digits after the decimal . Take $\pi = 3.14$
   - ***d)*** Draw a rough sketch of the curve representing the variation of the voltage u_C as a function of time.
   - ***e)*** Specify the mode of the electric oscillations that take place in the circuit.

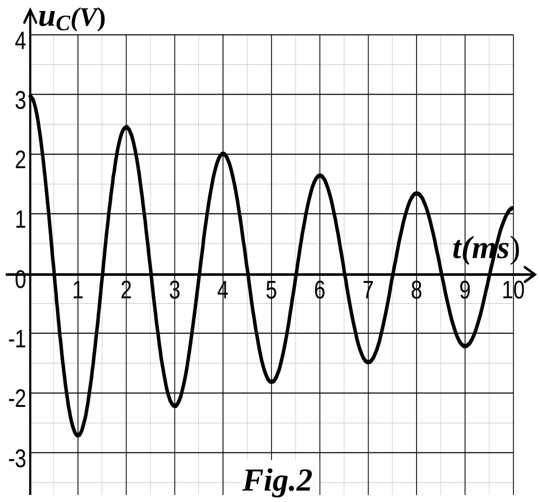


Fig.2

2) ***Second situation (real circuit)*** The variation of the voltage $u_{AM} = u_C$ is displayed on the screen of the oscilloscope as shown in the waveform of figure 2.
   - ***a)*** Specify the mode of the electric oscillations that take place in the circuit.
   - ***b)*** Give an energetic interpretation of the obtained phenomenon.
   - ***c)*** Referring to the waveform of figure 2,
     - ***i)*** Give the duration T of one oscillation;
     - ***ii)*** Compare T and T_0;
     - ***iii)*** Specify the value around which the voltage u_C varies.

3) ***Third situation***

We connect up a new circuit in which the coil, the uncharged capacitor and the switch K are connected in series across the generator G (Figure 3).

We close K at the instant $t_0 = 0$. At an instant t, the circuit carries a current i.

Figure 4 gives the variations, as a function of time, of i (Fig. 4a) and u_C (Fig. 4b).

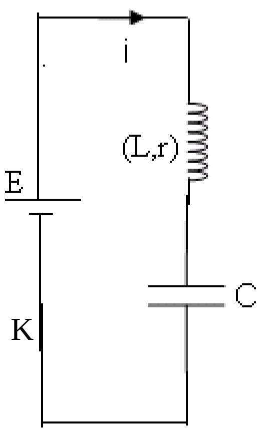


Fig.3

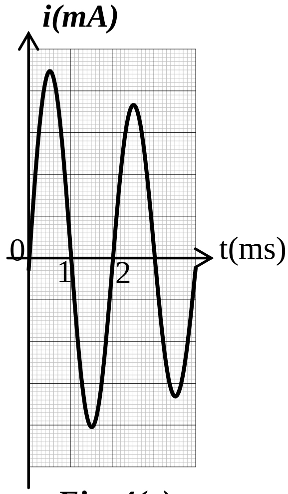


Fig. 4(a)

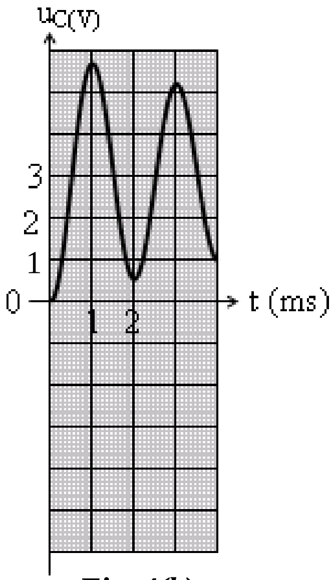


Fig. 4(b)

- ***a)*** Specify the value around which the voltage u_C varies.
- ***b)*** Give the duration of one oscillation.
- ***c)*** We consider the following 3 intervals of time : $0 \le t \le 0.5$ ms ; 0.5 ms $\le t \le 1$ ms ; 1 ms $\le t \le 1.5$ ms.

  Referring to the curves of figure 4, specify, with justification, the interval in which:
  - ***i)*** The coil supplies energy to the capacitor;
  - ***ii)*** The capacitor supplies energy to the coil;
  - ***iii)*** No energy exchange takes place between the coil and the capacitor.