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These files have been meticulously arranged by the

'Together We Can' team,

as we wish you the best of luck on your academic journey,

filled with happiness and success

Join us in creating a better tomorrow,
hand in hand!

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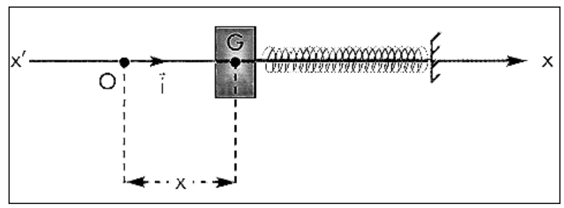
This exam is formed of three obligatory exercises in three pages numbered from 1 to 3. The use of non-programmable calculators is allowed.

First Exercise (7 points) Study of the motion of a horizontal elastic pendulum



The horizontal elastic pendulum of the figure below is formed of a solid (S) of mass m = 100 g and a spring of constant k = 80 N/m.
The center of mass G of (S) may move along a horizontal axis $(O, \vec{i})$.
At the instant $t_o = 0$, G being at rest at O, (S) is given an initial velocity $\vec{V}_0 = V_0\vec{i}$ (V_0 = 3 m/s). (S) thus oscillates around O. the abscissa of G at any instant during oscillations is x and its velocity is $\vec{V} = V\vec{i}$.
The horizontal plane containing G is taken as the gravitational potential energy reference.

A- Free undamped oscillations

In this part, we neglect the forces of friction.

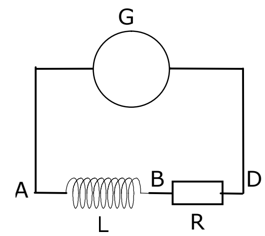
1) a) Write the expression of the mechanical energy of the pendulum [(S), spring] as a function of x and V.
   b) Is the mechanical energy of the pendulum conserved? Calculate its value.
2) Derive the second order differential equation that describes the motion of the center of mass G.
3) a) Verify that $x = x_m \cos(\omega_o t + \varphi)$ is a solution of this differential equation where $\omega_o = \sqrt{\frac{k}{m}}$.
   Calculate the values of x_m, φ and the proper period T_o of the pendulum.
   b) Determine the time interval after which G passes through the origin O for the first time.

B- Free damped oscillations

In this part, the forces of friction are not neglected and (S) performs damped oscillations of pseudo-period T.

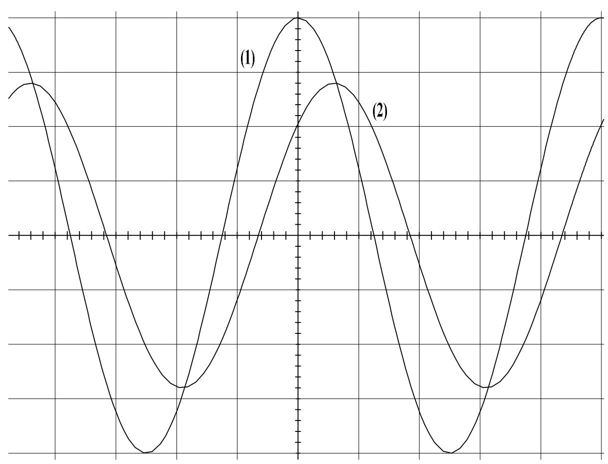
1) Is T smaller, equal or larger than T_o?
2) At the instant t = T, the speed of (S) is 2.8 ms^{-1}.
   a) What is the position of G at this instant?
   b) Calculate the work done by the forces of friction between the two instants $t_o = 0$ and t = T.

Second Exercise (7 points) Determination of the inductance of a coil



In order to determine the inductance L of a coil of negligible resistance, we connect this coil in series with a resistor of resistance R = 10 Ω across a low frequency generator G (Fig. 1). The generator G delivers an alternating sinusoidal voltage $v_G=V_m \cos \omega t$ (v_G in V, t in s).

1) Redraw the diagram of figure (1), showing the connections of the channels of an oscilloscope that allow us to display the voltages v_G across the generator and v_R across the resistor.
2) Which one of the two voltages v_G or v_R represents the alternating sinusoidal current in the circuit? Justify the answer.
3) In figure 2, the oscillogram (waveform) (1) displays the variation of the voltage v_G as a function of time. Justify specifying which of the oscillograms (1) or (2) leads the other. Determine the phase difference between the two oscillograms.



Time base: 5 ms/div
Vertical sensitivity on both channels: 1 V/div.

4) Determine, using the oscillograms, the angular frequency ω, the maximum value V_m of the voltage across the terminals of G and the amplitude I_m of the current carried by the circuit.
5) Write, as a function of time t, the expression of the current i and that of the voltage v_L across the coil.
6) Determine the value of L by applying the law of addition of voltages and giving t a particular value.

Third Exercise (6 points) Energy liberated by the disintegration of the cobalt

Given:

${}^{A}_{Z}X$	${}^{60}_{27}Co$	${}^{60}_{28}Ni$	${}^{0}_{-1}e$
Masse (en u)	59,9190	59,9154	0,00055

- 1 u = 931,5 MeV/c^2.
- Speed of light in vacuum: c = 3 x 10^8 ms^{-1}
- Planck's constant: h = 6.63 x 10^{-34} J.s
- Avogadro's constant: 6.02 x 10^{23} mol^{-1}.
- Molar mass of cobalt: 60 $g.mol^{-1}$.

1) Determine the remaining number of ${}^{60}_{27}Co$ nuclei and the activity of this sample at the end of 10.6 years.
2) One of the disintegrations of ${}^{60}_{27}Co$ gives rise to the nickel isotope ${}^{60}_{28}Ni$.
   a) Write, with justification, the equation of the disintegration of one cobalt nucleus ${}^{60}_{27}Co$. Identify the emitted particle.
   b) Calculate, in MeV, the energy liberated by this disintegration.
   c) Determine the energy liberated by the disintegration of 1 g of cobalt ${}^{60}_{27}Co$.
   d) Knowing that the energy liberated from the complete combustion of 1 g of coal is 30 kJ, find the mass of coal that would liberate the same amount of energy calculated in part c).

Solution

First Exercise (7 points)

1) $M.E_m = KE + PE_e = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$ (0.5 pt)

2)

a) The forces of friction are neglected, M.E is conserved

$M.E = ME_o = \frac{1}{2}mv_o^2 + \frac{1}{2}kx_o^2 = 0.45 + 0 = 0.45$ J. (0.75 pt)

b)

$$\frac{dM.E}{dt} = mvv' + kxx' = 0;\ v' = x'' \text{ and } x' = v$$

(0.75 pt)

$$x'' + \frac{k}{m}x = 0$$

3)

a) $x = x_m \cos(\omega_o t + \varphi)$; $x' = -x_m \omega_o \cos(\omega_o t + \varphi)$; $x'' = -x_m \omega_o^2 \cos(\omega_o t + \varphi)$

$x'' + \omega_o^2 x = -x_m \omega_o^2 \cos(\omega_o t + \varphi) + x_m \omega_o^2 \cos(\omega_o t + \varphi) = 0$

$x = x_m \cos(\omega_o t + \varphi)$ is a solution of the equation. (1 pt)

b) - $\omega_o = \frac{2\pi}{T_o} = \sqrt{\frac{k}{m}} \Rightarrow T_o = 2\pi\sqrt{\frac{m}{k}} = 0.22$ s (0.75 pt)

- $x = x_m$; $v = 0$ thus $M.E_m = \frac{1}{2}kx_m^2 = 0.45$ J $\Rightarrow x_m = 0.106$ m $= 10.6$ cm (0.75 pt)

- at $t = 0$, $x_o = 0 \Rightarrow \cos\varphi = 0$ and $v_o > 0 \Rightarrow \sin\varphi < 0$ thus $\varphi = -\frac{\pi}{2}$ rad . (0.5 pt)

c) (S) performs half a pseudo-period, $t = 0.11$ s. (0.25 pt)

B-

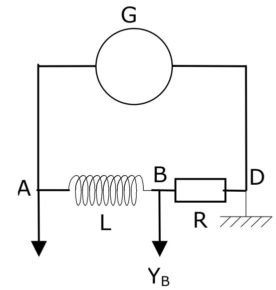
1) $T > T_o$. (0.25 pt)

2)

a) After a pseudo-period, (S) passes again through O. (0.25 pt)

b) $W_{\vec{f}} = \underset{t=0 \to t=T}{\Delta M.E} = ME_1 - M.E_o = 0.392 - 0.45 = -0.058$ J (1.25 pts)

1) (0.5 pt)



2) $v_R = Ri$, v_R represents then i to a constant factor. (0.5 pt)

3) v_1 becomes zero before v_2, thus $v_1 = v_G$ leads i ($v_2 = v_R$ represents i).

$T \rightarrow 5 \text{ div} \rightarrow 2\pi$

$0.6 \text{ div} \rightarrow \varphi \quad \Rightarrow \varphi = 0.24\pi = 0.75 \text{ rd}$ (1 pt)

4) $T = 5 \text{ (div)} \times 5 = 25 \text{ ms} \Rightarrow \omega = \frac{2\pi}{T} = 80\pi = 251 \text{ rad/s}$ (0.5 pt)

$V_m = 4 \text{ (div)} \times 1 = 4 \text{ V}$ (0.5 pt)

$V_{Rm} = 2.8 \text{ V} \Rightarrow V_{Rm} = I_m R \Leftrightarrow I_m = \frac{V_m}{R} = 0.28 \text{ A}.$ (1.5 pts)

5) i lags behind v_G by 0.75 rad;
$i = I_m \cos(\omega t - \varphi) = 0.28 \cos(80\pi t - 0.75)$

$u_L = L\frac{di}{dt} = -70.3 \, L \sin(80\pi t - 0.75)$ (1 pt)

6) $v_G = v_R + v_L = Ri + v_L$
$4 \cos(80\pi t) = 2.8 \cos(80\pi t - 0.75) - 70.3 \, L \sin(80\pi t - 0.75)$
for t = 0; L = 41 mH. (1.5 pt)

<u>Third Exercise</u> (6 points)

1) at $t_o = 0$ we have $N_o = \frac{m}{M} \times 6.02 \times 10^{23} = \frac{1}{60} \times 6.02 \times 10^{23} \approx 10^{22}$ nuclei. (0.5 pt)

at t = 2 T = 10.6 ans, $N = \frac{N_o}{2^2} = 25 \times 10^{22}$ nuclei. (0.5 pt)

$A = \lambda . N = \frac{\ln 2}{T} N = \frac{0.693}{T_{(s)}} N = 3.27 \times 10^{13}$ Bq . (1.25 pts)

2)

a) ${}^{60}_{27}Co \rightarrow {}^{60}_{28}Ni + {}^{A}_{Z}X$

The law of conservation of charge number gives: 27 = 28 + Z, thus Z = -1. (0.5 pt)
The law of conservation of mass number gives: 60 = 60 + A, thus A = 0. (0.5 pt)
The emitted particle is β^-.

Then : ${}^{60}_{27}Co \rightarrow {}^{60}_{28}Ni + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$ (1 pt)

b) $E = \Delta m \times c^2 = (m_{before} - m_{after})c^2 = (3.05 \times 10^{-3}) \times 931.5 = 2.84 \text{ MeV}$ (1 pt)

c) $E' = N_o \times E = 2.84 \times 10^{22} \text{ MeV} = 2.84 \times 10^{22} \times 1.6 \times 10^{-13} = 4.544 \times 10^9 \text{ J}.$ (0.25 pt)

d) $m_{coal} = \frac{4.544 \times 10^9}{30 \times 10^3} = 1.515 \times 10^5 \text{ g} = 151.5 \text{ kg}$ (0.5 pt)

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المديرية العامة للتربية
دائرة الامتحانات

امتحانات الشهادة الثانوية العامة
فرع علوم الحياة

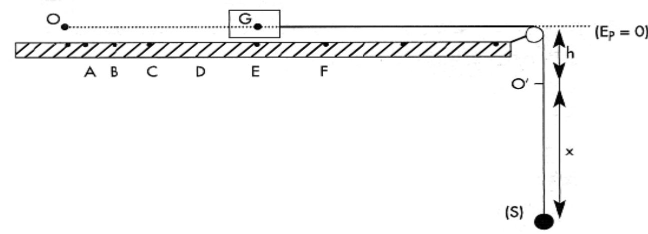
دورة سنة 2001 الاستثنائية

مسابقة في مادة الفيزياء
المدة : ساعتان

الاسم:
الرقم:

This exam is formed of three obligatory exercises in three pages numbered from 1 to 3. The use of non-programmable calculators is allowed.

<u>First Exercise</u> (7 points) **Verification of Newton's second**



In order to verify Newton's second law related to the dynamics of a solid in translation, we consider a puck of center of inertia G and of mass M = 200 g, a horizontal air table, a solid (S) of mass m = 50 g, an inextensible string and a pulley of negligible mass. We build the set up represented in the adjacent figure.

The part of the wire on the side of the puck is taut horizontally and the other part to the side of (S) is vertical.

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

At the instant t = 0, G is at O and the center of mass of (S) is at O', at a distance h below the reference. We release (S) without initial velocity, and, at the same time, the positions of G are recorded at successive instants separated by a constant time interval τ = 50 ms. At the instant t, G acquires a velocity $\vec{V}$ and (S) is found at a distance x below O'.

Neglect all frictions and take g = 10 m/s^2.

A- 1) Give the expression of the mechanical energy of the system (puck, string, (S), Earth) in terms of M, m, x, h, V and g. This energy is conserved. Why?

2) Deduce the expression of the acceleration of (S) in terms of g, m and M and calculate its value.

3) Draw a diagram showing the forces acting on the puck and determine, using the relation $\sum \vec{F} = M\vec{a}$, the force $\vec{T}$ exerted by the string on the puck.

B- By means of a convenient method, we determine the speed V of the puck. The results are tabulated as shown below:

Point	A	B	C	D	E
t in ms	50	100	150	200	250
V in cm/s	10	20	30	40	50

Determine, using the table, the linear momentums $\vec{P}_B$ at B and $\vec{P}_D$ at D and determine the ratio

$$\frac{\Delta\vec{P}}{\Delta t} = \frac{\vec{P}_D - \vec{P}_B}{\Delta t}.$$

C- Compare $\frac{\Delta\vec{P}}{\Delta t}$ and $\vec{T}$. Is Newton's second law thus verified? Justify.

Second Exercise (6 points) Determination of the capacitance of a capacitor

In order to determine the capacitance C of a capacitor, we connect up the circuit of figure 1. This circuit is formed of the capacitor, a generator of e.m.f. $E = 9$ V and of negligible internal resistance, two resistors of resistances $R_1 = 200$ KΩ and $R_2 = 100$ KΩ and two switches K_1 and K_2.

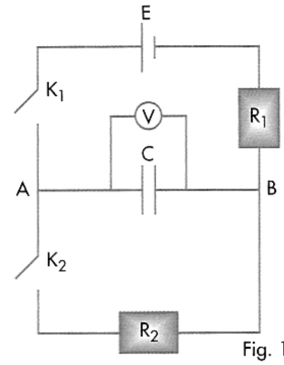


Fig. 1

I- Charging the capacitor

The capacitor being initially uncharged, we close K_1 and keep K_2 open. The capacitor will be charged.

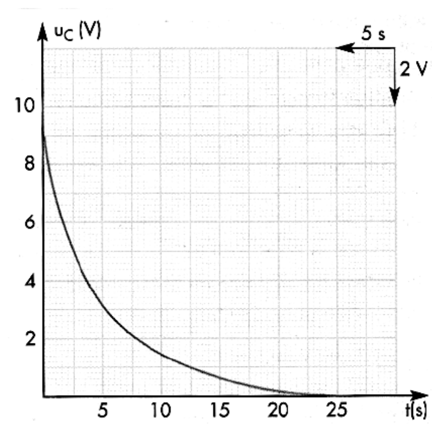
1) Derive the differential equation that describes the variation of the voltage $v_C = v_{AB}$ across the capacitor.
2) Knowing that the solution of this differential equation has the form $v_C = E(1 - e^{-\frac{t}{\tau_1}})$ expression of the constant τ_1 as a function of R_1 and C.
3) Knowing that, at the instant $t_1 = 20$ s, v_C has a value of 7.78 V, calculate the capacitance C of the capacitor.

II-Discharging the capacitor

The capacitor being charged under a voltage of 9 V, we open K_1 and close K_2.

The capacitor then discharges.

1) Draw a diagram of the circuit during that phase indicating the direction of the current.
2) Derive the differential equation that describes the variation of the voltages $v_C = v_{AB}$ across the capacitor.
3) Knowing that the solution of this differential equation is of the form $v_C = E\,e^{-\frac{t}{\tau_2}}$, deduce the expression of:
   a) the current i as a function of time. Take the direction of the current as a positive direction.
   b) the time constant τ_2 as a function of R_2 and C.



4) A convenient apparatus allows us to trace the graph of the variation of v_C as a function of time. (fig. 2)
   Determine from the curve the value of τ_2. Deduce the value of C.

III- What conclusion can be drawn about the two values of C? Comment.

Third Exercise (6 points) Controlled nuclear reaction

A chain nuclear reaction releases a considerable amount of energy. It may lead to an explosion if precautions were not taken. If this reaction is controlled inside a reactor, it may produce energy enough to function an electric power plant.

A- In a nuclear reactor of an atomic pile, the preparation of uranium 235, used as a fuel, takes place as follows:

1) The uranium nucleus $^{238}_{92}U$ captures a fast neutron and is transformed into a uranium nucleus $^{239}_{92}U$. Write the corresponding reaction.

2) The uranium nucleus 239 is radioactive, it is transformed into plutonium after two successive β^- dis-integrations according to the following reactions:

$$^{239}_{92}U \rightarrow {}^{A}_{Z}Np + {}^{0}_{-1}e + ...$$

$$^{A}_{Z}Np \rightarrow {}^{A_1}_{Z_1}Pu + {}^{0}_{-1}e + ...$$

Complete these reactions and determine Z, A, Z_1 and A_1 specifying the supporting laws.

3) The radioactive plutonium nucleus (Pu) is an α emitter. The daughter nucleus is the uranium 235 isotope. Some α particles are ejected with a kinetic energy of 5.157 MeV each and others with a kinetic energy of 5.144 MeV each.

a) Write the equation of the disintegration of (Pu) nucleus.

b) One of these α disintegrations is accompanied by the emission of a photon γ. Calculate the energy of this photon and deduce the wavelength of the associated radiation.

4) Uranium 235 is fissionable. During one of these possible fission reactions, the mass defect is 0.2 u. Calculate, in MeV and in J, the energy liberated by the fission of one nucleus of uranium 235.

B- In that atomic pile, a mass of 0.4 kg of uranium 235 is consumed in one day. The efficiency of the transformation of nuclear energy into electric energy is 30%. Calculate the electric power of this pile.

Given:

- $1\ u = 1,67 \times 10^{-27}$ kg = 931,5 MeV/c^2
- $c = 3x10^8$m/s
- Molar mass of ^{235}U = 235 g.mol^{-1}
- Avogadro's constant: $N = 6,02 \times 10^{23}\ mol^{-1}$
- $1\ MeV = 1,6 \times 10^{-13}$ J
- Plank's constant $h = 6,63 \times 10^{-34}$ J.s.

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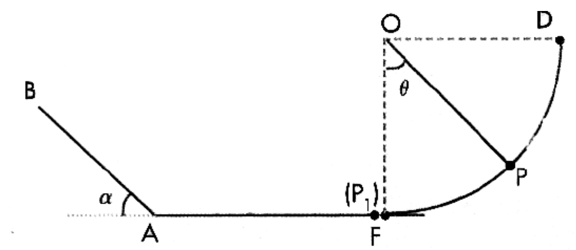
<u>First Exercise</u> (7 points) Conservation and non-conservation of the mechanical energy



Consider a material system (S) formed of an inextensible and mass less string of length l = 0.45 m, having one of its ends O fixed while the other end carries a particle (P) of mass m = 0.1 kg.
Take g = 10 m/s^2.
1) (S) is shifted from its equilibrium position by $\theta_m = 90°$, while the string is under tension, and then released without initial velocity.
Take the horizontal plane containing FA as a gravitational potential energy reference for the system [(S), Earth]. We neglect friction on the axis through O and air resistance.

a) Calculate the initial mechanical energy of the system [(S), Earth] when (P) was at D.
b) Determine the expression of the mechanical energy of the system [(S), Earth] in terms of l, m, g, V and θ, where V is the speed of (P) when the string passes through a position making an angle θ with the vertical.
c) Determine the value of θ, (0° < θ < 90°), for which the kinetic energy of (P) is equal to the gravitational potential energy of the system [(S), Earth].
d) Calculate the magnitude V_o of the velocity $\vec{V}_o$ of (P) as it passes through its equilibrium position.

2) Upon passing through the equilibrium position, the string is cut, and (P) enters in a head-on collision with a stationary particle (P_1) of mass ml= 0.2 kg. As a result, (P_1) is projected with a velocity $\vec{V}_1$ of magnitude V_1 = 2m/s. Determine the magnitude V of the velocity $\vec{V}$ of (P) right after impact knowing that $\vec{V}_o$, $\vec{V}_1$, and $\vec{V}$ are collinear.
Is the collision elastic? Justify your answer.

3) (P_1), being projected with a speed V_1 = 2m/s, moves along the frictionless horizontal track FA, and rises at A with the speed V_1, along the line of greatest slope of the inclined plane AB that makes an angle α = 30° with the horizontal.

a) Suppose now that the friction along AB is negligible. Determine the position of the point M at which (P_1) turns back.

b) In fact, AB is not frictionless; (P_1) reaches a point N and turns back, where AN = 20 cm. Calculate the variation in the mechanical energy of the system [(P_1), Earth] between A and N, and then deduce the magnitude of the force of friction (assumed constant) along AN.

<u>Second Exercise</u> (6 ½ points) **Determination of the capacitance of a capacitor**

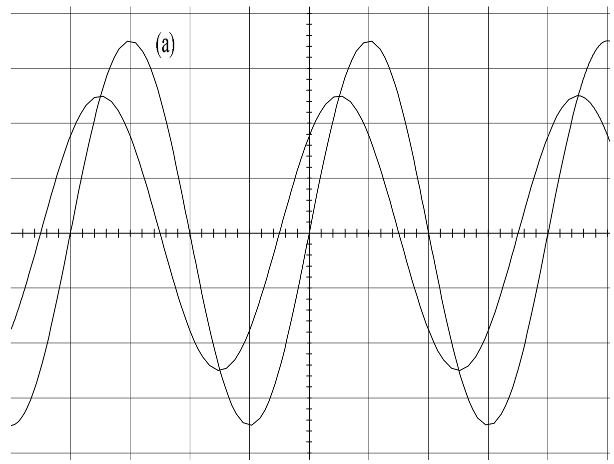
In order to determine the capacitance C of a capacitor, we use the following components:

- a function generator (LFG) delivering an alternating sinusoidal voltage: $v = V_m \cos \omega t$ (v in V and tin s), a resistor of resistance $R = 50\ \Omega$, a coil of inductance $L = 0.16$ H and of negligible resistance, an oscilloscope and connecting wires. Take $0.32\ \pi = 1$.

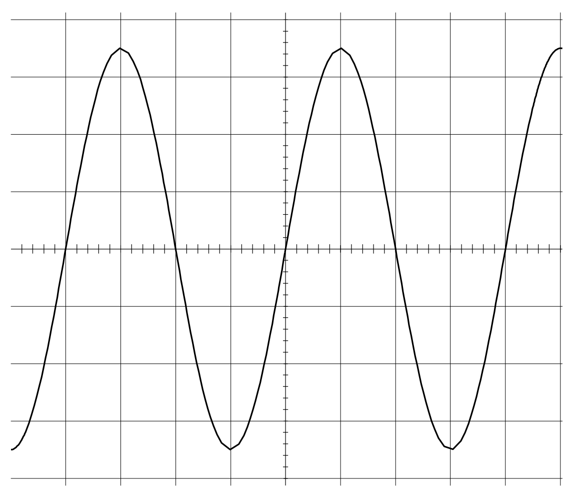
A) In a first experiment, we connect the capacitor in series with the resistor across the LFG. The oscilloscope is used to display the voltage v across the LFG on the channel Yl and the voltage vR across the resistor on the channel Y2. The adjustments of the oscilloscope are:

vertical sensitivity: 2 V/division on both channels,

horizontal sensitivity: 5 ms/division.



1) Draw again a diagram of the circuit showing on it the connections of the oscilloscope.
2) The waveforms displayed are represented as in the adjacent figure:
   a) Waveform (a) represents v. Why?
   b) Determine the frequency of the voltage v and the phase difference between v and vR.
   c) Using the numerical values of Vm and w, write the expressions of v and of vR as a function of time and deduce the expression of the instantaneous current i in the circuit.
   d) Knowing that the voltage vC across the capacitor is $v_C = \frac{q}{C}$ show that uC is given by $v_C = \frac{3.2\text{x}10^{-4}}{C}\cos(\omega t - \frac{\pi}{4})$
   e) Determine the value of C using the law of addition of voltages by taking a particular value of the time t.



B) In a second experiment, we insert the coil in series with the previous circuit.
We thus obtain an RLC series circuit and we keep the same connections of the oscilloscope.
We observe only one waveform on the screen (the two waveforms are confounded).
The above result shows evidence of an electric phenomenon that took place.
Name this phenomenon and calculate again the value of the capacitance C.

Third exercise (6.5 points) Radioactivity

Given the masses of the nuclei: m($^{131}_{53}I$) = 130.87697 u; m($^{A}_{Z}Xe$) = 130.87538 u; mass of an electron = 5,5 x 10^{-4} u;
1 u = 931.5 MeV/c^2; 1 MeV = 1.6 x 10^{-13} J; h = 6,63 x 10^{-34} J.s et c = 3x10^8m/s

In order to detect a trouble in the functioning of the thyroid, we inject it with a sample of an iodine radionuclide $^{131}_{53}I$. This radionuclide has a period (half-life) of 8 days and it is a β^- emitter. The disintegration of the nuclide $^{131}_{53}I$ gives rise to a daughter nucleus $^{A}_{Z}Xe$ supposed at rest.

1) a) The disintegration of a nucleus of $^{131}_{53}I$ is accompanied by the emission of a γ radiation. Due to what is this emission?
   b) Write the equation of the disintegration of $^{131}_{53}I$ nucleus.
   c) Calculate the decay constant of the radionuclide. Deduce the number of the nuclei of the sample at the instant of injection, knowing that the activity of the sample, at that instant, is 1.5 x 10^5 Bq.
   d) Calculate the number of the disintegrated nuclei at the end of 24 days.

2) a) Calculate the energy liberated by the disintegration of one nucleus of $^{131}_{53}I$.
   b) Calculate the energy of a γ photon knowing that the associated wavelength is 3.55 x 10^{-12}m.
   c) The energy of an antineutrino being 0.07 MeV, calculate the average kinetic energy of an emitted electron.
   d) During the disintegration of the $^{131}_{53}I$ nuclei, the thyroid, of mass 40 g, absorbs only the average kinetic energy of the emitted electrons and that of γ photons. Knowing that the dose absorbed by a body is the energy absorbed by a unit mass of this body, calculate, in J/Kg, the absorbed dose by that thyroid during 24 days.

Solution

First Exercise (7 points)

1)

a) At D: KE = 0 J car v = 0 m/s

$P.E_g = mgl = 0.1x10x0.45 = 0.45$ J

$M.E = KE + P.E_g = 0.45$ J (0.75 pt)

b)

$M.E = KE + P.E_g = \frac{1}{2}mv^2 + mgh$; et $h = l - l\cos\theta$

(0.75 pt)

$M.E = \frac{1}{2}mv^2 + mgl(1 - \cos\theta)$

c) M.E of the system [(S), Terre] is conserved because friction is neglected.

$M.E = M.E_D = 0.45$ J.

$P.E_g = K.E = \frac{M.E}{2} = 0.45 \text{ J} \Rightarrow P.E_g = mgl(1-\cos\theta) = 0.45 \Rightarrow \theta = 60^o$ (1 pt)

d) $M.E = M.E_F = 0.45$ J ; $P.E_{gF} = 0$.

$K.E = \frac{1}{2}mV_o^2 = 0.45 \Rightarrow V_o = 3$ m/s (0.5 pt)

2) During collision, the linear momentum of the system (P, P_1) is conserved:

$m\vec{V}_o = m\vec{V} + m_1\vec{V}_1$

$\vec{V}_o$, $\vec{V}$ et $\vec{V}_1$ are collinear: $mV_o = mV + m_1V_1 \Rightarrow V = \frac{mV_o - m_1V_1}{m_1} = -1$ m/s (1 pt)

$K.E_i$ of the system before collision: $K.E_i = \frac{1}{2}mV_o^2 = 0.45$ J.

$K.E_f$ of the system before collision: $K.E_f = \frac{1}{2}mV^2 + m_1V_1^2 = 0.45$ J.

$K.E_i = K.E_f \Rightarrow$ the collision is elastic. (0.75 pt)

3)

a) At A, $P.E_{gA} = 0 \text{ J} \Rightarrow M.E_A = K.E_A = \frac{1}{2}m_1V_A^2 = 0.4$ J.

M.E of the system [(S), Terre] is conserved because friction is neglected, $M.E_A = M.E_M$

At M, $E_{cM} = 0 \text{ J} \Rightarrow E_{mM} = E_{pM} = m_1gAM\sin\alpha = 0.4 \Rightarrow AM = 0.4$ m. (1 pt)

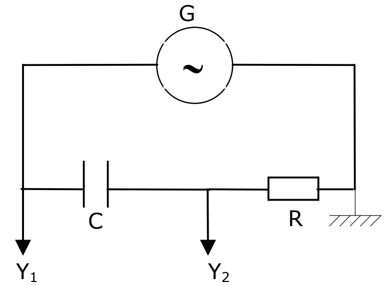
b) At N, $K.E_c = 0 \text{ J} \Rightarrow M.E_N = P.E_{gN} = m_1gAN\sin\alpha = 0.2$ J

$\Delta E_m = E_{mN} - E_{mA} = -0.20$ J

$\Delta E_m = W_{\vec{f}} = \vec{f}.\overline{AN} = -f \times AN \Rightarrow f = \frac{-\Delta E_m}{AN} = \frac{0.2}{0.2} = 1$ N (1.25 pts)

Second Exercise (6 ½ points)

1) (0.5 pt)



2)

a) $V_{m(a)} > V_{mb}$ (0.5 pt)

b) $T = 4(\text{div}) \times 5 = 20$ ms $\Rightarrow f = \frac{1}{T} = 50$ Hz

$T \rightarrow 4 \text{ div} \rightarrow 2\pi$

$0{,}5 \text{ div} \rightarrow \varphi \quad \Rightarrow \varphi = \frac{\pi}{4}$

v is lags behind i or v_R by $\frac{\pi}{4}$ rad. (1.25 pts)

c) $\omega = 2\pi f = 100\pi$ rad/s

$v = 7\cos 100\pi t$.

$V_{Rm} = 2{,}5(\text{div}) \times 2 = 5$ V

$v_R = 5\cos(100\pi t + \frac{\pi}{4})$ and $i = \frac{v_R}{R} = 0{,}1\cos(100\pi t + \frac{\pi}{4})$ (1.75 pts)

d) $i = \frac{dq}{dt} \Rightarrow q = \int i\, dt \Rightarrow u_C = \frac{q}{C} = \frac{1}{C}\int i\, dt = \frac{1}{C}\int[0{,}1\cos(100\pi t + \frac{\pi}{4})]\, dt = \frac{3{,}2\times10^{-4}}{C}\cos(\omega t - \frac{\pi}{4})$ (0.5 pt)

e) $v_G = v_R + v_C = Ri + v_C$

$7\cos 100\pi t = 5\cos(100\pi t + \frac{\pi}{4}) + \frac{3{,}2\times10^{-4}}{C}\cos(\omega t - \frac{\pi}{4})$

for t = 0: $7 = 5\frac{\sqrt{2}}{2} + \frac{3{,}2\times10^{-4}}{C} \times \frac{\sqrt{2}}{2} \Rightarrow C = 64\times10^{-6}$ F $= 64$ μF. (1 pt)

B- The phenomenon is the current resonance.

$f = f_o = \frac{1}{2\pi\sqrt{LC}} \Rightarrow C = \frac{1}{4\pi^2 f_o^2 L} = 64\times10^{-6}$ F $= 64$ μF (1 pt)

Third exercise (6.5 points)

1)

a) The emission of γ ray is due to the de-excitation of the daughter nucleus. (0.25 pt)

b) ${}^{131}_{53}I \rightarrow {}^{A}_{Z}Xe + {}^{0}_{-1}e + {}^{0}_{0}\overline{\nu} + {}^{0}_{0}\gamma$

The law of conservation of charge number gives: 53 = Z – 1 thus Z = 54.

The law of conservation of mass number gives: 131 = A thus A = 131. (0.75 pt)

c) $\lambda = \frac{\ln 2}{T} = \frac{0.693}{T_{(s)}} = 10^{-6}$ s. (0.5 pt)

$A_o = \lambda N_o \Rightarrow N_o = \frac{A_o}{\lambda} = 1.5\times10^{11}$ nuclei (0.5 pt)

d) t = 24 days = 3 T, and the number of disintegrated at the end of 3T is: $N-N_o$

$N = \frac{N_o}{2^3} \Rightarrow N - N_o = 1.31\times10^{11}$ nuclei (1 pt)

2)

a) (1 pt)

$E = \Delta m \times c^2 = (m_{before} - m_{after})c^2 = (0.00104)\times931.5 = 0.96876 \text{ MeV} = 0.96876\times1.6\times10^{-13} = 1.55\times10^{-13}$ J

b) $E_{ph} = \frac{hc}{\lambda} = 5.6\times10^{-14}$ J = 0.35 MeV (0.75 pt)

c) The principe of conservation of energy gives:

$E = K.E(Xe) + E_{ph} + E(\overline{\nu}) + K.E(\beta^-)$

$0.96876 = 0 + 0.35 + 0.07 + K.E(\beta^-) \Rightarrow K.E(\beta^-) = 0.55 \text{ MeV} = 0{,}88\times10^{-13}$ J

(0.5 pts)

d) The energy absorbed by the thyroid during the disintegration of a single nucleus is:

$E_1 = 0.55 + 0.35 = 0.9$ MeV

For t = 24 days, $E_2 = E_1 \times 1.31\times10^{11} = 1.18\times10^{11} \text{ MeV} = 1.89\times10^{-2}$ J

$D = \frac{E_2}{mass} = \frac{1.89\times10^{-2}}{0.04} = 0.47$ J/kg (1.25 pts)

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فرع علوم الحياة

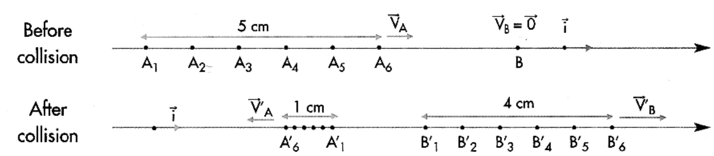
دورة سنة 2002 الاستثنائية

مسابقة في الفيزياء المدة : ساعتان	الاسم: الرقم:

This exam is formed of three obligatory exercises
in three pages numbered from 1 to 3.
The use of non-programmable calculators is allowed.

<u>First Exercise</u> (7 points) Collision and the laws of conservation

In order to study the collision between two bodies, we use a horizontal air table that is equipped with a launcher and two pucks (A) and (B) of respective masses $m_A = 0.2$ kg and $m_B = 0.3$ kg.



(A), thrown with the velocity $\vec{V}_A = V_A \vec{i}$, enters in a head-on collision with (B), initially at rest. (A) rebounds with the velocity $\vec{V}'_A = V'_A \vec{i}$, and (B) is projected with the velocity $\vec{V}'_B = V'_B \vec{i}$.
The figure below shows, in real dimensions, a part of the dot-prints, that register the positions of the centers of masses of (A) and (B), obtained when the time interval separating two successive dots is $\tau = 20$ ms.

A) Law related to the linear momentum

I) 1) Show, using the above dot-prints, that the velocities V_A, V'_A and V'_B are constant and calculate the algebraic values $\vec{V}_A$, $\vec{V}'_A$ and $\vec{V}'_B$.

2) Determine the linear momentums $\vec{P}_A$ and $\vec{P}'_A$ of the puck (A), before and after collision respectively and that $\vec{P}'_B$ of the puck (B) after collision.

3) Deduce the linear momentums, $\vec{P}$ and $\vec{P}'$, of the center of mass of the system [(A) and (B)] before and after collision respectively.

4) Compare $\vec{P}$ and $\vec{P}'$ then conclude.

II) 1) Name the forces acting on the system [(A), (B)].

2) What is the value of the resultant of these forces?

3) This result agrees with the conclusion of (I - 4). Why?

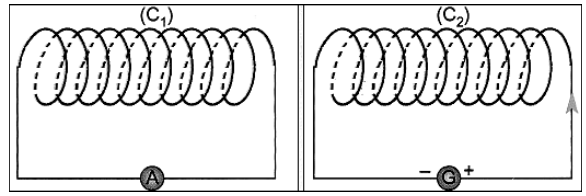
B) **Law related to the kinetic energy**

1) Calculate the kinetic energy of the system [(A), (B)] before and after collision.

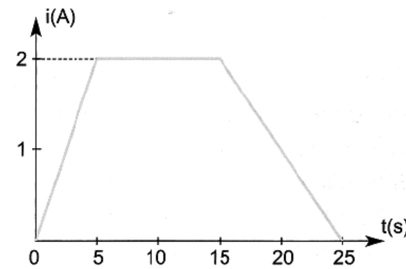
2) Deduce the nature of this collision.

Second Exercise (7 points) The transformer

The purpose of this exercise is to study the principle of functioning of an ideal transformer and its role.
Consider two coils, (C_1) of 1000 turns and (C_2) of 500 turns; the surface area of each of the turns of (C_1) and (C_2) is 100 cm^2.



A) Principle of functioning



The coil (C_1) is connected to a sensitive ammeter (A) and the coil (C_2) is connected across a generator thus forming two closed circuits. (Fig. 1)
The coil (C_2) carries then a current i that varies with time as shown in the graph of figure 2. As a resultat, (C_2) produces, through (C_1), a magnetic field $\vec{B}$ supposed uniform of magnitude $B = 2\times10^{-3}\,i$ (B in T and i in A).

1) Give the expression of the magnetic flux crossing (C_1) in terms of i.
2) Give the expression of e, the e.m.f. induced in (C_1).
3) Find the values of e for $0s \le t \le 25\,s$.
4) Trace the graph giving the variation of e as a function of time t for $0s \le t \le 25\,s$.
   Scale: on the time axis: 1cm → 5 s and on the axis of e: 1cm → 4 mV.
5) Draw again figure 1 and indicate, using Lenz's law, the direction of the current induced in (C_1), i the interval of time $0s \le t \le 5\,s$.

B) Role

The coils (C_1) and (C_2), disconnected from the preceding circuit, are used to construct an ideal transformer (T) using a convenient iron core. (C_1) and (C_2) are respectively the primary and the secondary.

1) We connect across (C_1) a sinusoidal alternating voltage of effective value $V_1 = 220$ V. A voltmeter, in AC mode connected across (C_2), reads a value V_2.
   a) Give a simplified diagram of (T).
   b) Does (T) act as a step-up or a step-down transformer? Justify your answer and calculate V_2.

2) A lamp, connected across the terminals of (C_2), carries a current of effective value $I_2 = 1$ A. Calculate the effective current I_1 carried by the coil (C_1).

Third exercise (6 points) Nuclear fission

Given: mass of a neutron: $m_n = 1.00866$ u

mass of a 235 uranium nucleus : $m(^{235}U) = 234.99342$ u

mass an iodine nucleus A: $m(^{A}I) = 138.89700$ u

mass of a 94 yttrium nucleus 94: $m(^{94}Y) = 93.89014$ u

$1\ u = 1.66054 \times 10^{27}$ kg $= 931.5\ MeV/c^2$.

$1\ eV = 1.6 \times 10^{-19}$ J

In a nuclear power station, the fissionable fuel is made up of 235 uranium nuclei. The nuclei that undergo a nuclear reaction must have been bombarded with a thermal neutron.

1) One of the possible reactions that the uranium 235 undergoes has the form of:

$${}_{0}^{1}n + {}_{92}^{235}U \rightarrow {}_{53}^{A}I + {}_{Z}^{92}Y + 3{}_{0}^{1}n + \gamma.$$

a) The 235 uranium nucleus is fissionable. Why?

b) The nuclear reaction that the 235 uranium nucleus undergoes is said to be provoked. A provoked reaction is one of two types of nuclear reactions. Name the other type and tell how it can be distinguished from the other.

c) Determine the values of A and Z specifying the supporting laws.

d) Calculate the energy liberated during the preceding reaction.

In what form does this liberated energy appear?

2) The nuclear power station converts 30% of the liberated energy into electrical energy.

Calculate the mass of 235 uranium consumed by the power station during one day if the electric power it supplies is 6×10^8 W.

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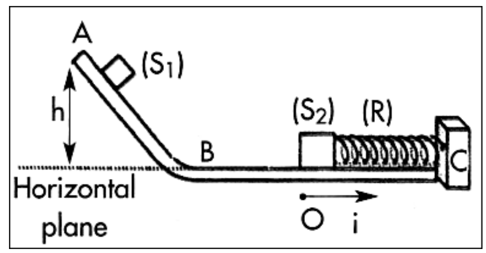
	مسابقة في الفيزياء المدة : ساعتان	الاسم : الرقم :

This exam is formed of three obligatory exercises
in three pages numbered from 1 to 3.
The use of non-programmable calculators is allowed.

<u>First Exercise</u> (6 ½ points) Determination of the force constant of a spring

In order to determine the force constant k of a spring (R) of un-jointed turns, we consider:

- a frictionless track ABC found in a vertical plane,
- a spring (R) having one end fixed to a support C and its other end connected to a solid (S_2) of mass m_2 of negligible dimensions.
- a solid (S_1) of mass $m_1 = 0.1$ kg and of negligible dimensions held at A at height h = 0.8 m above the horizontal plane containing BC.



The horizontal plane containing BC is taken as the gravitational potential energy reference. Take g = 10 m/s^2.

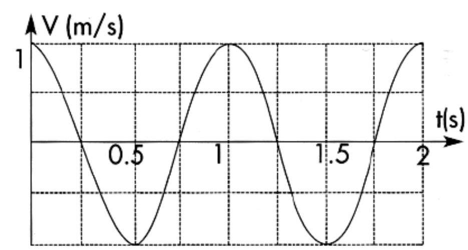
1- (S_1), released from rest at A, reaches (S_2) with a velocity $\vec{V}_1$. Show that the magnitude of $\vec{V}_1$ is $V_1 = 4$ m/s.

2- (S_1), collides with (S_2) and sticks to it, thus forming a particle (S). Determine, in terms of m_2, the expression of V_o the magnitude of the velocity $\vec{V}_o$ of (S) just after the impact.

3- The system [(S), (R)] forms a horizontal elastic pendulum, (S) oscillating around its equilibrium position at O.

a- Determine the differential equation that describes the motion of the oscillator. Deduce the expression of its proper period T_o.

b- Figure (2) represents the variation of the algebraic value of the velocity of (S) as a function of time.
The origin of time corresponds to the instant when the velocity of (S) is $\vec{V}_o$.



i- Give the value V_o of $\vec{V}_o$.
ii- Deduce the value of m_2.
iii- Give the value of T_o.
iv- Calculate k.

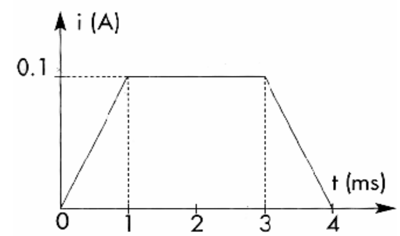
Second Exercise (7 points) Role and characteristics of a coil

Consider a coil (B) that bears the following indications: $L = 65$ mH and $r = 20\ \Omega$.

A- Role of a coil

In order to show the role of a coil, we connect the coil across a generator G_1.

The variation of the current i carried by the coil as a function of time is represented in figure (1).



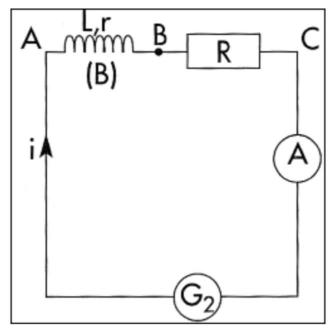
1- a- Give, in terms of L and i, the literal expression of the induced electromotive force e produced across the coil.

b- Determine the value of e in each of the following time intervals: [0; 1ms], [1 ms; 3 ms], [3 ms; 4 ms].

2- In what time interval would the coil act as a generator? Justify your answer.

B- Characteristics of the coil

In order to verify the values of L and r, we perform the two following experiments:

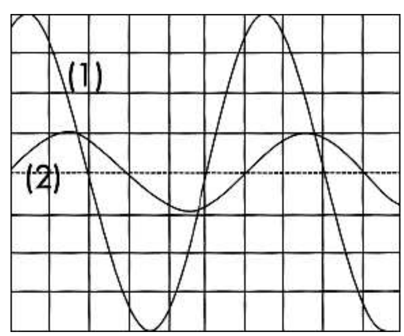


I- **First experiment:** The coil (B), a resistor of resistance $R = 20\ \Omega$ and an ammeter of negligible resistance are connected in series across a generator (G_2) of electromotive force $E = 4$ V and of negligible internal resistance (figure 2). After a certain time, the ammeter reads $I = 0.1$ A. Deduce the value of r.

II- **Second experiment:** The ammeter is removed and G_2 is replaced by a generator G_3 delivering an alternating sinusoidal voltage.

1- Redraw figure (2) and show on it the connections of an oscilloscope that allows to display, on the channel (1), the voltage v_g across the generator and, on channel (2), the voltage v_R across the resistor.

2- The voltages displayed on the oscilloscope are represented on figure (3).



Given: vertical sensitivity on both channels: 2 V/division.
horizontal sensitivity: 1 ms/division.

a- The waveform (1) represents v_g. Why?

b- The voltage across the generator has the form: $v_g = V_m \cos\omega t$. Determine U_m and ω.

c- Determine the phase difference φ between v_g and v_R.

d- Determine the expression of the instantaneous current i carried by the circuit.

e- Using the law of addition of voltages at an instant t, and using a particular value of t, deduce the value of the inductance L.

III- Compare the values found for r and L, with those indicated on the coil.

Third exercise (6 ½ points) The two aspects of light

To show evidence of the two aspects of light, we perform the two following experiments:

A- First experiment

We cover a metallic plate by a thin layer of cesium whose threshold wavelength is $\lambda_o = 670$ nm. Then we illuminate it with a monochromatic radiation of wavelength in vacuum $\lambda = 480$ nm. A convenient apparatus is placed near the plate in order to detect the electrons emitted by the illuminated plate.

1- This emission of electrons by the plate shows evidence of an effect. What is that effect?

2- What does the term "threshold wavelength" represent?

3- Calculate, in J and eV, the extraction energy (work function) of the cesium layer.

4- What is the form of energy carried by an electron emitted by the plate? Give the maximum value of this energy.

Given: Planck's constant: $h = 6.6 \times 10^{-34}$ J.s;
speed of light in vacuum: $c = 3 \times 10^{8}$ m/s;
1 eV= 1.6×10^{-19} J.

B- Second experiment

The two thin slits of Young's apparatus, separated by a distance a, are illuminated with a laser light whose wavelength in vacuum is $\lambda = 480$ nm. The distance between the screen of observation and the plane of the slits is D=2m.

1- Draw a diagram of the apparatus and show on it the region of the interference.

2- The conditions to obtain the phenomenon of interference on the screen are satisfied. Why?

3- Due to what is the phenomenon of interference?

4- **a-** Describe the aspect of the region of interference observed on the screen.

b- We count 11 bright fringes. The distance between the centers of the farthest fringes is $l = 9.5$ mm. What do we call the distance between the centers of two consecutive bright fringes? Calculate its value and deduce the value of a.

C- The two experiments show evidence of two aspects of light. Specify the aspect shown by each experiment.

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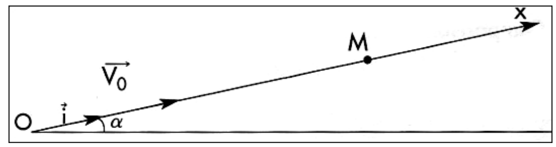
This exam is formed of three obligatory exercises in three pages numbered from 1 to 3. The use of non-programmable calculators is allowed.

First Exercise (6 points) Graphical study of energy exchange



Consider an inclined plane that makes an angle α with the horizontal ($\sin \alpha = 0.2$) and a marble (B) of mass m = 100 g, taken as a particle. We intend to study the energy exchange between the system (marble, Earth) and the surroundings.

To do that, the marble (B) is given, at the instant $t_o = 0$, the velocity $\vec{V}_o = V_o \vec{i}$ along the line of greatest slope OX. Given $V_o = 4\ m.s^{-1}$ and $g = 10\ m/s^2$.

The horizontal plane through point O is taken as the gravitational potential energy reference.

A- The forces of friction are supposed negligible.

1- Determine the value of the mechanical energy M.E of the system (marble, Earth).

2- At the instant t, the marble passes through a point M of abscissa OM = x. Determine, as a function of x, the expression of the gravitational potential energy $P.E_g$ of the system (marble, Earth) when the marble passes through M.

3-a) Trace, on the same system of axes, the curves representing the variations of the energies M.E and $P.E_g$ as a function of x.

Scale: - on the axis of abscissas: 1 cm represents 1 m;
- on the axis of energy: 1 cm represents 0.2 J.

b) Determine, using the graph, the speed of the marble for x = 3 m.

c) Determine, using the graph, the value of x_m of x for which the speed of (B) is zero.

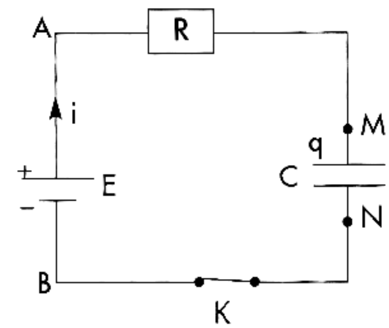
B-1. In reality, the speed of the marble becomes zero at a point of abscissa x = 3 m. The forces of friction are no longer negligible. Calculate then the work done by the forces of friction between x = 0 and x = 3 m.

2. The system (marble, Earth) thus exchanges energy with its surroundings. In what form and by how much?

<u>Second Exercise</u> (7 points) Responseof an RC series circuit

The object of this exercise is to distinguish the response of an RC series circuit when we apply across its terminals a constant voltage, from its response when it carries a constant current.

A- Case of a constant voltage



The circuit of the adjacent figure allows us to charge the capacitor of capacitance $C = 10\ \mu F$ through a resistor of resistance $R = 100\ k\Omega$, under a constant voltage $E = 9V$. Take the instant $t = 0$ the instant when the switch K is closed.

1- Denote by $u_C = u_{MN}$, the instantaneous value of the voltage across the terminals of the capacitor.

a- Show that the differential equation in u_C is of the form:

$$u_C + RC\frac{du_C}{dt} = E$$

b- Knowing that the solution of this equation has the form: $u_C = A(1 - e^{-\frac{t}{\tau}})$ determine A and τ.

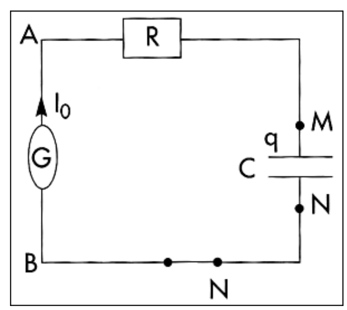
c-Trace the shape of the curve that gives the variation of u_C as a function of time.

2- a- Determine the expression of the voltage $u_R = u_{AM}$ as a function of time.

b- Trace, on the same system of axes, the shape of the curve giving the variation of u_R as a function of time.

3- What is the value of the interval if time t_A at the end of which u_C becomes practically 9V?

B- Case of a constant current



The preceding capacitor being discharged is to be recharged through the same resistor by a generator giving a constant current $I_o = 0.1$ mA.

1-a- Show that the charge q can be written, in SI, in the form $q = 10^4$ x t.

b- The voltage $u_R = u_{AM}$ across the resistor remains constant. Determine its value.

c- Trace the shape of the graph representing u_R.

2-a- Determine the expression of the voltage $u_C = u_{MN}$ as a function of time.

b- Trace the shape of the graph representing u_C.

c- Determine the time interval t_B needed for the voltage u_C to attain the value 9 V.

C- Conclusions

1- Using the preceding graphs, specify the case where the voltage across the capacitor attains, in the steady state, a limiting value.

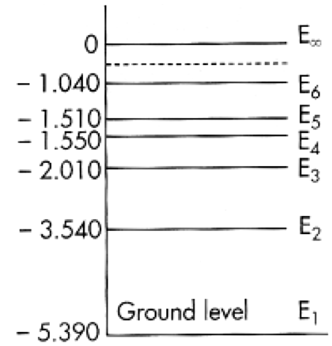
2- A camera is equipped with a flash that is formed of the preceding RC circuit. We intend to take the largest number of photos in a given time interval. To do so we have to charge the capacitor. Which one of the two preceding charging modes is more convenient? Why?

Third exercise (6 ½ points) The isotope $^{7}_{3}Li$ of lithium

As all the other chemical elements, the isotope $^{7}_{3}Li$ has properties that distinguish it from other chemical elements.

The object of this exercise is to show evidence of some properties of the isotope $^{7}_{3}Li$.

A- Emission spectrum of the lithium atom



The adjacent figure represents the energy levels of the lithium atom.

1-Calculate, in joule, the energy (E_1) of the atom when it is in the ground state and (E_5) when it is in the fifth state.

2-During the downward transition (de-excitation) from different energy levels to the ground level, the lithium atom emits some radiations.

a- Calculate the highest and the lowest frequency of the emitted radiations.

b- The corresponding emission spectrum is discontinuous. Why?

3- The lithium atom, being in the ground state, captures:

a- a photon whose associated radiation has a wavelength of $\lambda = 319.9$ nm. Show that the atom absorbs this photon. In what level would it be?

b- a photon of energy 6.02 eV. An electron is thus liberated. Calculate, in eV, the kinetic energy of that electron.

B- Nuclear reaction

A nucleus $^{A}_{Z}X$, at rest, is bombarded by a proton carrying an energy of 0.65 MeV; we obtain two α particles.

1- Is this nuclear reaction spontaneous or provoked? Justify your answer.
2- Determine the values of Z and A by applying the convenient conservation laws. Identify the nucleus X.
3- Calculate the mass defect due to this reaction and deduce the corresponding energy liberated.
4- Knowing that the two obtained α particles have the same kinetic energy E. Calculate E.

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

1 u = 931.5 MeV/c^{2};

mass of the nucleus of lithium: m (Li) = 7.01435 u;

mass of the a particle: m(α) = 4.00150 u;

mass of a proton: m_p = 1.00727 u.

This exam is formed of three obligatory exercises in three pages
The use of non-programmable calculators is allowed

First Exercise **(7 points)** **Suspension system in a car**

Certain tracks present periodic variations of its level .A car moves in a uniform motion on such a track that has regularly spaced bumps. The distance between two consecutive bumps is d and the speed of the car is V. In order to study the effect of the bumps on the car , we consider the car and the suspension system as a mechanical oscillator (elastic pendulum) whose oscillation takes a time T.

A- Study of T

1. **Theoretical study**

Consider a horizontal elastic pendulum formed of a solid of mass m attached to a spring of constant k and of negligible mass; the other end of the spring is fixed to a support. The forces of friction are supposed to be negligible and the solid of center of mass G can move on a horizontal axis Ox.
When the solid is at rest , G coincides with the point O taken as origin of abscissa.
The solid is pulled from its equilibrium position by a distance x_m, and then released without initial velocity at the instant $t_o = 0$. The horizontal plane passing through G is taken as a gravitational potential energy reference
At any instant t , the abscissa of G is x and the algebraic measure of its velocity is v.

a) Starting from the expression of the mechanical energy of the system {pendulum -Earth}, determine the second order differential equation that characterizes the motion of the solid.
b) Deduce the expression of its proper period T_o .

2. **Experimental study**

In order to show the effects of the mass m of the solid and the constant k of the spring on the duration of one oscillation of a horizontal elastic pendulum, we use four springs of different stiffnesses and four solids of different masses.
In each experiment , we measure the time Δt for 10 oscillations using a stopwatch .

a) Effect of the mass m of the solid

In a first experiment , the four solids are connected separately from the free end of the spring whose stiffness is k = 10 N/m. The values of Δt are shown in the following table:

m (g)	50	100	150	200
Δt (s)	4.5	6.3	7.7	8.9

Determine, using the table, the ratio T^2 / m. Conclude.

b) Effect of the stiffness k of the spring.

In a second experiment , the solid of mass m = 100 g is connected successively from the free end of each of the four springs. The new values of Δt are shown in the following table :

k (N/m)	10	20	30	40
Δt (s)	6.3	4.5	3.7	3.2

Determine, using the table , the values of the product $T^2 \times k$. Conclude.

c) Expression of T

Deduce that T may be written in the form $T = A\sqrt{\frac{m}{k}}$ where A is a constant.

B) Oscillations of the car

1) The car ,with the driver alone ,form a mechanical oscillator whose proper period is around 1s .It moves with a speed V = 36 km / h on a path having equally spaced bumps .The distance between two consecutive bumps is d = 10 m. The car enters then in resonance.

a) Specify the exciter and the resonator.

b) Explain why does the car enter resonance.

c) How can the driver avoid this resonance?

2)The driver, with four passengers , drives his car on the same path with the same speed of 36km/h. Would the car enter in resonance? Justify your answer.

Second Exercise (6 points) Energy levels of the hydrogen atom

The energies of the different energy levels of the hydrogen atom are given by the relation:

$$E_n = -\frac{13.6}{n^2} \text{ (in eV)} \qquad \text{where } n \text{ is a positive whole number.}$$

Given :

Planck's constant : $h = 6.63 \times 10^{-34}$ J.s ; $1 \text{ eV} = 1.60 \times 10^{-19}$ J ;

Speed of light in vacuum : $c = 3 \times 10^8$ m/s ; $1 \text{ nm} = 10^{-9}$ m.

A- Energy of the hydrogen atom

1) The energies of the atom are quantized. Justify this using the expression of E_n .

2) Determine the energy of the hydrogen atom when it is:

a) in the fundamental state .

b) in the second excited state.

3) Give the name of the state for which the energy of the atom is zero.

B - Spectrum of the hydrogen atom

1 - Emission spectrum

The Balmer's series of the hydrogen atom is the set of the radiations corresponding to the downward transitions to the level of n = 2.

The values of the wavelengths in vacuum of the visible radiations of this series are :

411 nm ; 435 nm ; 487 nm ; 658 nm.

a) Specify, with justification, the wavelength λ_1 of the visible radiation carrying the greatest energy.

b) Determine the initial level of the transition giving the radiation of wavelength λ_1 .

c) Deduce the three initial levels corresponding to the emission of the other visible radiations.

2 - Absorption spectrum

A beam of Sunlight crosses a gas formed mainly of hydrogen . The study of the absorption spectrum reveals the presence of dark spectral lines.

Give , with justification, the number of these lines and their corresponding wavelengths.

C - Interaction photon - hydrogen atom

1) We send on the hydrogen atom , being in the fundamental state, separately, two photons of respective energies 3.4 eV and 10.2 eV .

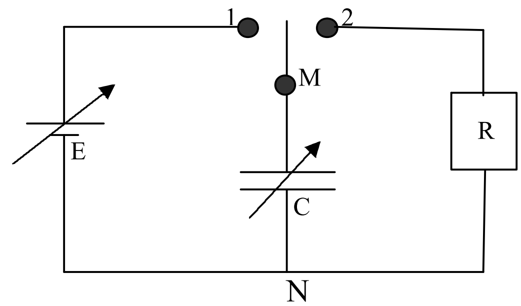
Specify, with justification , the photon that is absorbed .

2) A hydrogen atom found in its fundamental state absorbs a photon of energy 14.6 eV.The electron is thus ejected.

a. Justify the ejection of the electron.

b. Calculate, in eV, the kinetic energy of the ejected electron.

<u>Third Exercise</u> (7 points) <u>Saving life capacitor</u>



A heart suffering from disordered muscular contractions is treated by applying electric shocks using a convenient apparatus.

In order to study the functioning of this apparatus , we use a source of DC voltage of adjustable value E , a double switch , a resistor of resistance R and a capacitor (initially neutral) of adjustable capacitance C. We connect the circuit represented in the adjacent figure.

A. Theoretical study

1. The switch is turned to position (1).

a) Give the name of the physical phenomenon that takes place in the capacitor.

b) Specify the values of the current in the circuit and the voltage u_{MN} after few seconds.

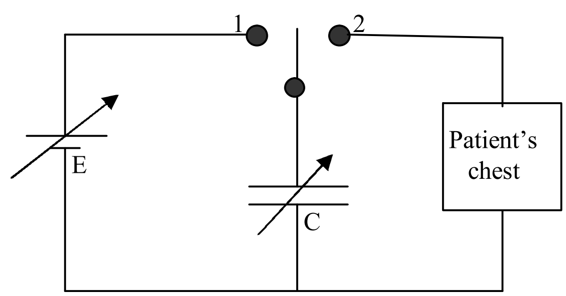
2. The switch is now turned to position (2) at an instant taken as $t_o = 0$.

a) Derive , at the instant t , the differential equation giving the variation of the voltage $u_C = u_{MN}$ as a function of time.

b) The expression $u_C = A\,e^{-\frac{t}{\tau}}$, where A and τ are constants , is a solution of that equation. Determine the expressions of A and τ in terms of E, R and C.

c) Derive the expression giving the current i during the discharging as a function of time.

B. Using the apparatus



The energy needed to save the life of a patient during an electric shock is 360 J. This energy is supplied by discharging the capacitor through the patient's chest (ribcage) considered as a resistor of resistance 50 Ω during a time t_1 that can be controlled by the switch.

The capacitance of the capacitor is adjusted on the value C = 1 millifarad and is charged under the voltage E = 1810 V.

1) Determine the energy stored in the capacitor at the end of the charging process.

2) The discharging starts at the instant $t_o = 0$ .At the instant t_1 , the energy delivered to the patient amounts to 360J ,the switch is then opened .

a) Calculate the energy that remains in the capacitor at the instant t_1.

b) Using the results of the above theoretical study; determine:

i) the value of t_1 .

ii) the current at the end of the electric shock.

First Exercise

A) 1 – a) M.E = $\frac{1}{2}kx^2 + \frac{1}{2}mv^2$;

No friction the M.E is conserved $\Rightarrow \frac{dM.E}{dt} = 0 \Rightarrow kxv + mvx'' = 0$

$\Rightarrow x'' + \frac{k}{m}x = 0$

b) $\omega_0^2 = \frac{k}{m} \Rightarrow \omega_0 = \sqrt{\frac{k}{m}}$; $T_0 = \frac{2\pi}{\omega_0}$

$\Rightarrow T_0 = 2\pi\sqrt{\frac{m}{k}}$

2 – a) $\frac{T^2}{m} = 4$ (S.I) $\Rightarrow \frac{T^2}{m}$ = constant

b) $T^2\times k = 4$ (S.I) $\Rightarrow T^2\times k$ = constant

c) T is proportional $\sqrt{m}$ to and T is inversely proportional to $\sqrt{k}$

$\Rightarrow T = A\sqrt{\frac{m}{k}}$

B) 1 – a) Exciter is the bumps and the resonator is the car

b) The car is submitted to pulses periodically of period : $T' = \frac{d}{V}$ =1sec

T_0 = 1 sec ; $T' = T_0 \Rightarrow$ Resonance

c) Mass increases $\Rightarrow T_0$ increases

$\Rightarrow T_0 \neq T'$

Second Exercise

A) 1 – $E_1 = -13.6$ eV ; $E_2 = -3.4$ eV ; $E_3 = -1.51$ eV ; $E_\infty = 0$

$\Rightarrow$ The values of energies are discontinuous .

2 – a) $E_{fund.}$ corresponding to n = 1 $\Rightarrow E_{fund.} = -13.6$ eV

b) Second excited state corresponding to n = 3

$\Rightarrow E_3 = -1.51$ eV.

3 – Ionize state

B) 1 – a) $E = \frac{hc}{\lambda}$ or E is inversely prop. to λ

$\Rightarrow \lambda_1 = 411$ nm

b) $\frac{hc}{\lambda} = E_i - E_f \Rightarrow \frac{hc}{\lambda} = (\frac{-13.6}{n^2} + \frac{13.6}{4})\ 1.6 \times 10^{-19}$ J ;

For $\lambda = \lambda_1$; n = 6

c) The other three levels are : n = 5 ; n = 4 ; n = 3 to n = 2

2 – The dark lines of the absorption spectrum corresponding to the bright lines of same wavelength of the emission spectrum .

We have 4 bright lines $\Rightarrow$ we have 4 dark lines of wavelengths : 411 nm ; 487 nm ; 658 nm

C) 1 - $-13.6 + 3.4 = -10.2 = \frac{-13.6}{n^2} \Rightarrow n = 1.15$;

n is not a whole number $\Rightarrow$ not absorbed

$-13.6 + 10.2 = -3.4 = \frac{-13.6}{n^2} \Rightarrow$ n = 2 (whole no) $\Rightarrow$ absorbed

2 - a) The energy of the photon is greater than the ionization energy

b) K.E = -13.6 + 14.6 = 1 eV

c)

Third Exercise

A) **1** – a) Charging of the capacitor

b) $i = 0$; $u_C = E$.

2 – a) $u_C = Ri = -RC\frac{du_C}{dt}$

$\Rightarrow u_C + RC\frac{du_C}{dt} = 0$

b) At t = 0 ; $u_C = A = E$; Derive u_C and substitute $\Rightarrow \tau = RC$

c) $i = -C\frac{du_C}{dt} \Rightarrow i = \frac{E}{R}e^{-\frac{t}{\tau}}$

B) **1** – $E = \frac{1}{2}CU^2 \Rightarrow E = 1638$ J

2 – a) $E_{rem.} = 1638 - 360 = 1278$ J

b) i) $E_{rem.} = \frac{1}{2}Cu_C^2$

$\Rightarrow u_C = 1599$ V ;

$u_C = E\,e^{-\frac{t}{\tau}} \Rightarrow t = 6.2$ ms

ii) $i = \frac{E}{R}e^{-\frac{t}{\tau}} \Rightarrow i = 32$ A

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دائرة الامتحانات

امتحانات شهادة الثانوية العامة
فرع علوم الحياة

دورة سنة ٢٠٠4 الاستثنائية

مسابقة في الفيزياء المدة: ساعتان	الاسم: الرقم:

This exam is formed of three obligatory exercises in three pages numbered from 1 to 3.
The use of non-programmable calculators is allowed.

First exercise (6 pts) Determination of the speed of a bullet

A gun is used to shoot bullets, each of mass m = 20 g, with a horizontal velocity $\overrightarrow{V_0}$ of value V_0.
In order to determine V_0, we consider a setup formed of a wooden block of mass M = 1 kg, suspended from the ends of two inextensible sting of negligible mass and of the same length (figure 1).
This setup can be taken as a block of wood suspended from the free end a string of length ℓ = 1 m, initially at rest in the equilibrium position at G_1.
A bullet having the velocity $\overrightarrow{V_0}$ hits the block and is embedded in at the level of the center of mass G of the block.
Just after impact, the system (block, bullet) moves with a horizontal velocity $\overrightarrow{V_1}$. The pendulum thus attains a maximum angular deviation $\alpha = 37^o$.
G_1 and G_2 are the respective positions of G in the equilibium position and in the highest position.
Take the horizontal plane throug G_1 as a gravitational potential energy reference (figure 2).
Neglect friction with air and take $g = 9{,}8$ m/s^2.

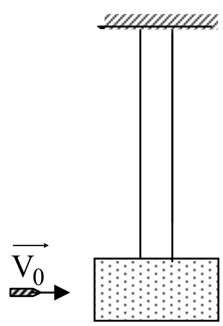


Figure 1

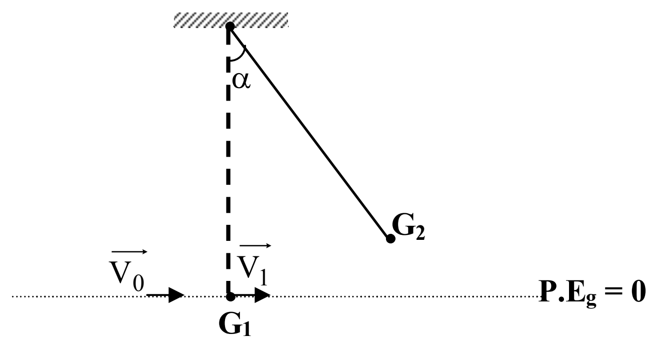


Figure 2

1. During a collision, which one of the two physical quantities, the linear momentum or the kinetic energy of the system does not remain always conserved?
2. Determine the expression of the value of V_1 of the velocity $\overrightarrow{V_1}$ in terms of M, m and V_0.
3. **a)** Determine, just after impact, the mechanical energy of the system (pendulum, Earth) in terms of V_0, M, and m.
   b) Determine, in terms of M, m , g, ℓ and α, the mechanical energy of the system (pendulum, Earth) at point G_2.
   c) Deduce the value of V_0.
4. Verify the answer of question (1).

Second exercise (7 pts) Determination of the nature and the characteristics of an electric components

Consider three electric components of different natures. One of these components is a resistor of resistance R, another one a capacitor of capacitance C and the last one of inductance L and of negligible resistance.

A- Nature of each component

In order to determine the nature of each component, we consider a DC generator G, a resistor of resistance r, an ammeter A and a switch K.

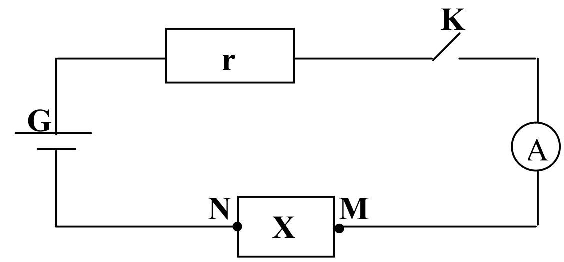


Figure 1

1. First experiment

We connect the circuit represented in figure (1).
We connect, between M and N, one of the components called X, and, then, we close K. The ammeter reads then a certain value which decreases to zero after a certain time.
Determine the nature of the component X.

2. Second experiment

We perform the above experiment again by replacing the component X by the component, called Y. The ammeter reads, in this case, a constant value.
Determine the nature of the component Y.

3. The third component, called Z, is connected alone between M and N. Indicate its nature and specify its effect on the growth of the current in the circuit.

B- Characteristics of the components

1. Value of C

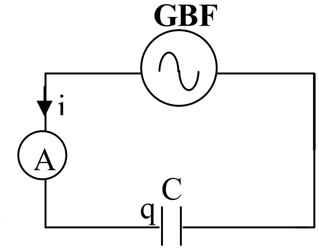
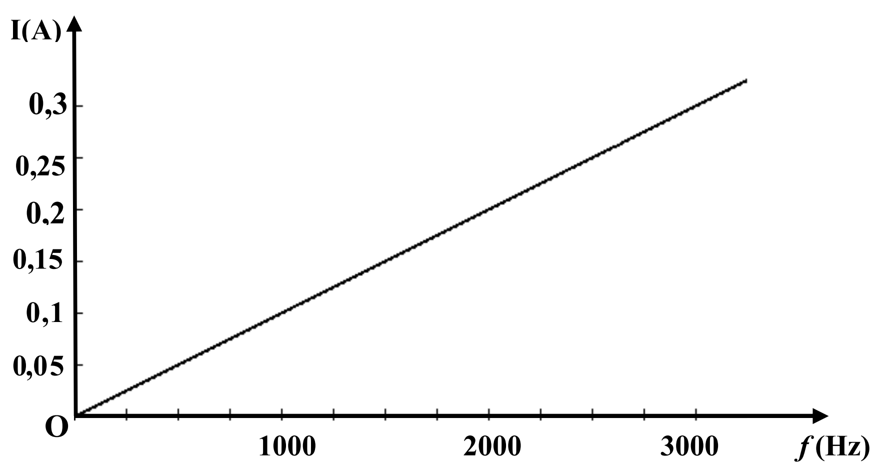


Figure 2

The capacitor of capacitance C is fed by a function generator (LFG) [figure 2] delivering a sinusoidal alterning voltage $u = U\sqrt{2}\sin 2\pi f t$, of effective value U =1V and adjustable frequency **f**. Take $0{,}32\,\pi = 1$.
We give **f** different values, and we measure, using the ammeter the corresponding values of the effective current. I carried by the circuit. The graph of figure (3) represents the variation of I as a function of **f**.

Figure 3



a) According to the graph, we can write I = B x **f** where B is a constant. Calculate B..
b) Using the relation i = dq/dt, give the expression of B in terms of U and C.
c) Determine the value of C .

2. Value of L

The three components X, Y and Z are now connected in series across the given function generator (LFG). (figure 4).
f is made to vary while keeling the effective value U. We find that the effective current I carried by the circuit attains a maximum value I_0 for $\mathbf{f_0}$ = 20 Hz.

a. The existence of the maximum value I_0 of I shows evidence of a physical phenomenon. Give the name of this phenomenon.
b. Knowing that $C = 1{,}6 \times 10^{-5}$ F, determine the value of L.

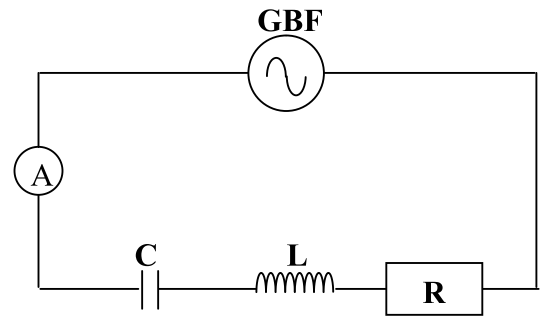


Figure 4

Third exercise (7 pts) The carbon 14

The object of this exercice is to show evidence of some characteristic properties of the radio element $^{14}_{6}C$ and to show the preocedure followed to know the age of a wooden fossil.

Given :

mass of a proton : m_p = 1,00728 u ; mass of a neutron : m_n = 1,00866 u ;
mass of a nucleus $^{14}_{6}C$ = 14,0065 u ; mass of a nucleus $^{14}_{7}N$ = 14,0031 u ;
1 u = 931,5 MeV/c^2 ; Molar mass of $^{14}_{6}C$ = 14 $g \times mol^{-1}$;
Avogadro's number : $\mathcal{N} = 6{,}02 \times 10^{23}$ mol^{-1}.

A - Formation of carbon 14

In the high atmosphere the carbon isotope $^{14}_{7}$N is obtained by the impact of a nitrogen $^{14}_{6}C$ with a neutron.

1. The nuclides $^{12}_{6}C$ and $^{14}_{6}C$ are two isotopes. Why?
2. Write the equation of the formation of $^{14}_{6}C$.
3. Identify the emitted particle.

B – Disintegration of carbon 14

Carbon14 is radioactive β^- emitter. It disintegrates to give nitrogen $^{14}_{7}$N.

1. The emission of a β^- particle is due to the disintegration of a nucleon inside the nucleus.
2. Calculate the binding energy per nucleon of each of the nuclei $^{14}_{6}C$ and $^{14}_{7}$N.
3. In fact, a radioactive decay leads to a more stable state. Justify this statement taking into account the preceding results.
4. The activity of a substance containing carbon 14 is determined using a counter of β^- particles. A sample of wood containing 0.05g of carbon 14 of radioactive period T = 5570 years is exposed to the counter.
Determine:
a) The radioactive constant λ of carbon 14.
b) The number of carbon 14 nucle contained in this sample at the instant of exposure.
c) The activity of the sample at the considered instant.

C- Age of a wood fossil

We intend to determine the age of a piece of wood fossil. We expose this piece to the counter of β^- particles; it indicates 100 disintegration in 5 minutes. Knowing that a piece of the same wood, freshly cut, gives 1000 disintegrations in 5 minutes, determine the age of the wood fossil.

Solution

First exercise (6 pts.)

1. The kinetic energy of the system (bullet, block) **(1/4pt.)**

2. $\vec{P}_{\text{before}} = \vec{P}_{\text{after}}$ **(1/4 pt)**

m $\vec{V_0}$ = (M+m)$\vec{V_1}$ **(1/4 pt)** Thus : $V_1 = \dfrac{mV_0}{(M+m)}$ **(1/4 pt.)**

3. a. M.E = P.E$_g$ + K.E **(1/4pt.)**

M.E = 0 + K.E = $\frac{1}{2}(M+m)V_1^2$ **(1/4pt.)**

M.E = $\frac{1}{2}$ (M+m)$[\dfrac{mV_0}{(M+m)}]^2 = \dfrac{1}{2}\dfrac{m^2V_0^2}{(M+m)}$ **(1/4 pt.)**

b. M.E= (M+m)gh **(1/4pt.)**

h = l - lcosα = l (1-cosα) **(1/2pt)**

Thus : M.E = (M+m)g l (1-cosα) **(1/4pt.)**

c. The friction is neglected and the M.E of (pendulum, Earth) is conserved. (**1/2pt.)**

$\dfrac{1}{2}\dfrac{m^2V_0^2}{(M+m)}$ = (M+m)g l (1-cosα)

$V_0 = \dfrac{(M+m)}{m}\sqrt{2gl(1-\cos\alpha)}$ **(1pt.)**

V_0 = 101,3 m/s **(1/2 pt.)**

4. K.E$_{\text{before}}$ = ½ m V_0^2 **(1/4pt)**

K.E$_{\text{before}}$ = 102,6 J **(1/4pt)**

K.E$_{\text{after}}$ = ½ (M+m)V_1^2

$= \dfrac{1}{2}\dfrac{m^2V_0^2}{(M+m)}$ **(1/4pt)**

E$_{\text{after}}$ = 2 J **(1/4pt)**

K.E$_{\text{before}}$ is ≠ from K.E$_{\text{after}}$ **(1/4pt)**

Second exercise (7 pts.)

A-

I. X is a capacitance because the current decreases till zero. **(3/4 pt.)**

2. Y is a resistance because the value of the current remains constant. **(3/4 pt)**

3. Z is a coil of inductance. It delays the growth of the current. **(3/4 pt)**

B-1.a) B = 10^{-4} A / Hz **(1 pt)**

b) We have : i = $\frac{dq}{dt} = \frac{Cdu_C}{dt}$

i = C U $\sqrt{2}$ 2π f cos2π ft .Or i = I $\sqrt{2}$ cos2π ft =>

I = 2π C U f = B f $\Rightarrow$ B = 2π C U **(13/4pt.)**

c) C = B / 2π U = 10^{-4} / 2π = 16×10^{-6} F **(1/2 pt)**

2.a) Current resonance phenomenon. **(1/2 pt)**

b) $f_0 = \frac{1}{2\pi\sqrt{LC}}$ **(1/2 pt)**

$\Rightarrow$ L = 0,11 H. **(1/2 pt)**

Third exercise (7 pts)

A-1) The nuclides have have the same charge number Z and the numbers of masse A is different. **(1/2 pt.)**

2) $^{14}_{7}N + ^{1}_{0}n \longrightarrow ^{14}_{6}C + ^{1}_{1}p$ **(3/4 pt.)**

3) The emitted particle is a proton (or hydrogen nucleus) **(1/4pt.)**

B-1. $^{1}_{0}n \longrightarrow ^{0}_{-1}e + ^{1}_{1}p$ **(3/4 pt.)**

2. The binding energy of the nucleus of mass mx is : $E_b = \Delta m.c^2$ **(1/4pt.)**

with Δm = [Zm_p+ (A-Z)m_n] – m_x **(1/4pt)**

The binding energy per nucleon is $\frac{E_b}{A}$.**(1/4pt)**

- For the nucleus $^{14}_{6}C$ we have :

Δm =6 × 1,00728+8 × 1,00866- 14,0065

Δm = 0,10646 u ; E_l = 99,16749 MeV

$\frac{E_b}{A}$ = 7,083 MeV **(1/2 pt)**

- For the nucleus $^{14}_{7}N$ we have ;

Δm =7 × 1,00728+7 × 1,00866- 14,0031

Δm = 0,10848 u ; E_l = 101,04912 MeV

$\frac{E_b}{A}$ = 7,217 MeV **(1/2 pt)**

3. The nucleus $^{14}_{7}N$, has a binding energy per nucleon more than that of $^{14}_{6}C$; the nucleus $^{14}_{7}N$ is more stable from the nucleus $^{14}_{6}C$. **(1/4pt)**

4.a) $\lambda = \frac{0,693}{T}$; **(1/4pt)**

λ =1,244×10^{-4} year^{-1} =3,94 × 10^{-12} s^{-1} **(1/4pt)**

b) $n = \frac{0,05 \times 6,02 \times 10^{23}}{14} = 215 \times 10^{19}\ nuclei$ **(1/2pt)**

c) A= $\lambda \times n$ **(1/4 pt)** ; A=8471 × 10^{10} Bq. **(1/4pt)**

C- A_0= 200 des./mn A= 20 des./mn

$A = A_0 e^{-\lambda t}$ **(1/4pt)** ; $t = \frac{\ln \frac{A_0}{A}}{\lambda}$ = 18509 years **(1pt)**

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مسابقة في الفيزياء المدة : ساعتان	الاسم : الرقم :

This exam is formed of three obligatory exercises in three pages numbered from 1 to 3.

The use of non-programmable calculators is allowed.

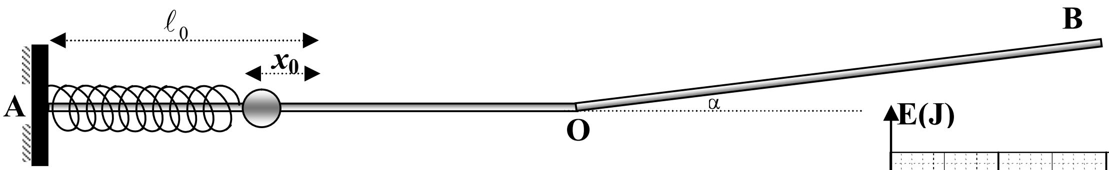
<u>First Exercise</u> (6 ½ pts) <u>Determination of the value of a force of friction</u>

A solid (S) of mass m = 200 g is free to move on a track AOB lying in a vertical plane. This rail is formed of two parts: the first one AO is straight and horizontal and the other OB is straight and inclined by an angle α with respect to the horizontal ($\sin\alpha = 0.1$). Along the part AO, (S) moves without friction, and along the part OB, (S) is acted upon by a force of friction $\vec{f}$ that is assumed constant and parallel to the path.

The object of this exercise is to determine the magnitude f of the force $\vec{f}$ of friction.

A- Launching the solid

In order to launch this solid on the part AO, we use a spring of constant k = 320 N / m and of free length ℓ_0 ; one end of the spring is fixed at A to a support. We compress the spring by x_o; we place the solid next to the free end of the spring and then we release them. When the spring attains its free length ℓ_0, the solid leaves the spring with the speed $V_0 = 8$ m/s; it thus slides along the horizontal part and then rises up at O the inclined part OB.



1) Determine the value of x_o.

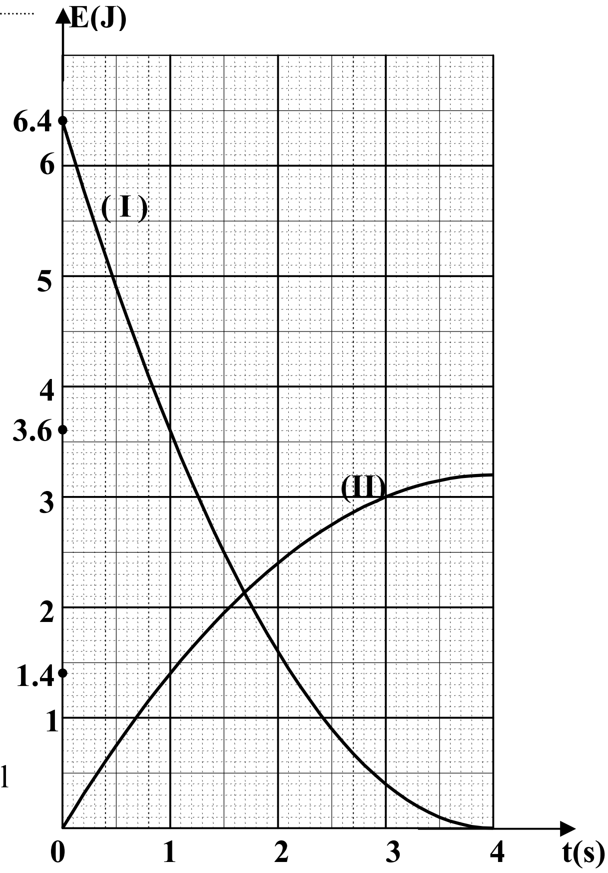
2) The solid reaches O with the speed $V_0 = 8$ m/s. Justify.

B- Motion of the solid along the inclined part OB

(S) moves, at O, up the inclined part OB with the speed V_0 at the instant $t_o = 0$. A convenient apparatus is used to trace, as a function of time, the curves representing the variations of the kinetic energy K.E of the solid and the gravitational potential energy $P.E_g$ of the system (solid - Earth). These curves are represented in the adjacent figure between the instants $t_o = 0$ and $t_4 = 4$ s, according to the scale:

- 1 division on the time axis corresponds to 1 s
- 1 division on the energy axis corresponds to 1 J.

The horizontal plane through point O is taken as a gravitational potential energy reference. Take $g = 10\ m / s^2$.



1) The curve **(I)** represents the variation of the kinetic energy K.E of (S) as a function of time. Why?

2) Using the curves:

a) specify the form of the energy of the system at the instant $t_4 = 4$ s. Justify your answer.

b) determine the maximum distance covered by the solid along the part OB.

c)i) complete the table with the values of the mechanical energy M.E of the system at each instant t.

t (s)	0	1	2	3	4
M.E (J)		5			

ii) justify the existence of a force of friction $\vec{f}$.

iii) calculate the variation in the mechanical energy of the system between the instants $t_o = 0$ and $t_4 = 4$ s.

iv) determine f .

<u>Second Exercise</u> (7pts) <u>Determination of the inductance of a coil</u>

In order to determine the inductance L of a coil of negligible resistance, we put this coil with a resistor of resistance R = 10 Ω and a capacitor of capacitance $C = \frac{160}{\sqrt{3}}$ μF all in series across a generator G of adjustable frequency delivering an alternating sinusoidal voltage $u_{AM} = U_m \sin(2\pi f t)$ (figure 1). The circuit thus carries an alternating sinusoidal current i.

An oscilloscope is connected so as to display the voltage u_{AM} on the channel Y_1 and the voltage u_{DM} on the channel Y_2.

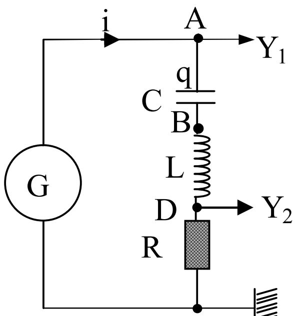


Fig. 1

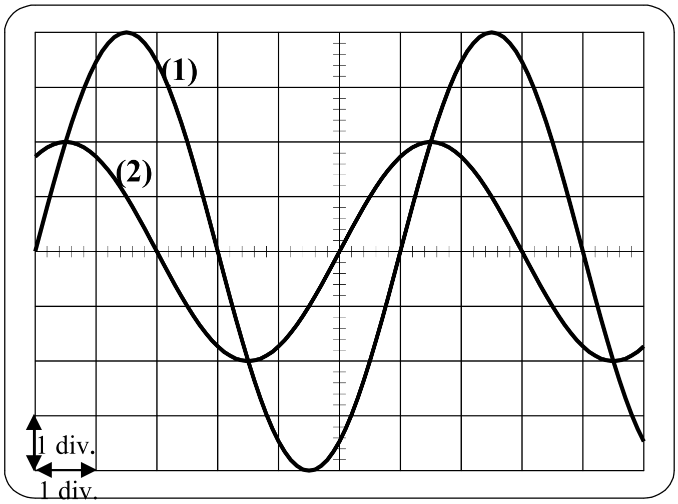


Fig. 2

A) The frequency of u_{AM} is adjusted at f = 50 Hz.

The waveforms of figure 2 show the curve (1) corresponding to the voltage u_{AM} and the curve (2) that corresponds to the voltage u_{DM}. The vertical sensitivity on both channels is 5 V / division.

Given: $\sqrt{3} = 1.73$ $0.32\,\pi = 1$

1) Referring to the waveforms:

a) calculate the maximum voltage U_m across the generator.

b) show that the expression of the voltage u_{DM} may be written in the form:

$$u_{DM} = 10 \sin(100\pi t + \frac{\pi}{3}) \quad (u_{DM} \text{ in V, t in s}).$$

2) a) Determine the expression of i.

b) Show that the expression of the voltage across the terminals of the capacitor can be written as:

$$u_C = u_{AB} = -20\sqrt{3}\cos(100\pi t + \frac{\pi}{3})$$

c) Determine the expression of the voltage u_{BD} across the coil in terms of the inductance L and time t.

3) The relation $u_{AM} = u_{AB} + u_{BD} + u_{DM}$ is valid at any instant t. Deduce the value of L.

B) In order to verify the value of L obtained in part **A-*3***, we vary the frequency f of the voltage delivered by G, keeping the same value of the maximum voltage U_m. We notice that the two voltages u_{AM} and u_{DM} become in phase when the value of the frequency is $f_0 = 70.7$ Hz.

1) Give the name of the electric phenomenon that takes place.

2) Determine again the value of L.

Third Exercise (6 ½ pts) Radioactivity

A physics laboratory is equipped with a radioactivity counter together with a source of radioactive cesium $^{137}_{55}Cs$ which is a β^- emitter.

The technical data sheet of the counter carries the following indications:

- *nuclide :* $^{137}_{55}Cs$
- *half-life :* $T = 30$ *years*
- *activity of the source at the date of fabrication of the counter :* $A_0 = 4.40 \times 10^5$ *Bq*
- *energy of beta radiation : 0.514 MeV*
- *energy of gamma radiation : 0.557 MeV*

Take : 1 eV = 1.6×10^{-19} J. 1 u = 931.5 MeV / c^2

Masses of nuclei and particles: m (Cs) = 136.8773 u ; m (Ba) = 136.8756 u ; m (electron) = 5.5×10^{-4} u

A- Energy liberated by a cesium nucleus

1- a) Write the equation of the decay of cesium 137, knowing that the daughter nucleus is $^{y}_{x}Ba$. Determine x and y.

b) The barium $^{y}_{x}Ba$ obtained is in an excited state. Write the equation of the downward transition of the barium nucleus.

2-a) Calculate, in MeV, the energy E liberated during the disintegration of a cesium nucleus.

b) Starting from the technical data sheet, deduce the energy carried by the antineutrino neglecting the kinetic energy of the barium nucleus.

B- Activity of cesium

1. At the beginning of the school year 2004, we measure, using the counter, the activity A of the source. We obtain the value 3.33×10^5 Bq. Determine the year of fabrication of the counter equipped with its source knowing that $A = A_0.e^{-\lambda t}$, λ being the radioactive constant of cesium.

2. The activity of the source remains practically the same within one hour. Starting from the definition of the activity of a radioactive source, deduce the number n of disintegrations that cesium undergoes within one hour.

C- Consequences of using the cesium source

1. Having calculated the values of E and n, calculate, in J, the energy received by a student within one hour of experimental work in the laboratory knowing that the student absorbs 1% of the liberated nuclear energy.

2. Knowing that the maximum nuclear energy that a student may absorb within one hour without any risk is 1.2×10^{-4} J, verify that student is not subject to any danger.

First Exercise :

A- 1) Explanation (**1/2pt) ;** $\frac{1}{2}k(x_o)^2 = \frac{1}{2}m(V_0)^2$………. **(1/2 pt)**

x_0 = 20 cm ………………………………………….**(1/2 pt)**

2) The method of conservation of M.E or $\Sigma \vec{F} = \vec{P} + \vec{N} = \vec{0}$, the motion is thus URM with a speed same as V_0 = 8 m/s . … **(1/2pt)**

B- 1) At the instant t= 0, the speed of the solid is 8m/s, its K.E is maximum. The curve **I** passes through a maximum then. **(1/2pt)**

t (s)	0	1	2	3	4
M.E (J)	6.4	5	4	3.4	3.2

2) a) At the instant t = 4 s, K.E = 0 , The energy of the system then is gravitational potential .
…………………… …**(1/2pt)**

b) The maximum distance corresponds to the maximum value of the gravitational P.E on the curve II ;

$P.E_{gmax}$= 3.2 J = mgh_{max} = mg $d_{max}\sin\alpha$, thus : d_{max}= 16 m **(1pt).**

c) i. Table ……………………………………………… **(1pt)**

ii. The mechanical energy decreases with time ;
this means that friction exists. **(1/4pt)**

iii. ΔM.E = 3.2 – 6.4 = - 3.2 J **(1/2pt)**

iv. Δ M.E = W($\vec{f}$) = - $f \times d_{max}$ **(1/2pt)**

$f = \frac{3.2}{16} = 0.2N$ **(1/2pt)**

Second Exercice:

A- 1- a)$U_m = 4$ div$\times$ 5 V/div = 20 V **(1/2pt)**

b) $U_{DMm} = 2$ div $\times$ 5 V/div = 10V

The phase difference between u_{DM} and u_{AM} is

$$\varphi_1 = 1\text{div}\times \frac{2\pi}{6} = \frac{\pi}{3}\text{rad}$$

u_{DM} leads $u_{AM.}$

$u_{DM} = 10\sin(100\pi t + \frac{\pi}{3})$ **(1 ½ pt)**

2) a) $u_{DM} = Ri$ => $i = \sin(100\pi t + \frac{\pi}{3})$ **(1/2pt)**

b) $i = C\frac{du_C}{dt}$ **(1/4pt)** => u_C = primitive de $\frac{1}{C}i$ **(1/4pt)**

$= -20\sqrt{3}\cos(100\pi t + \frac{\pi}{3})$ **(1/4pt)**

(1pt)

c) $u_{BD} = L\frac{di}{dt}$ **(1/4pt)**

$= 100\pi L\cos(100\pi t + \frac{\pi}{3})$ **(1/2pt)**

3) The relation $u_{AM} = u_{AB} + u_{BD} + u_{DM}$ can be written as :

$$20\sin 100\pi t = -20\sqrt{3}\cos(100\pi t + \frac{\pi}{3}) + 100\pi L\cos(100\pi t + \frac{\pi}{3})$$
$$+10\sin(100\pi t + \frac{\pi}{3})$$ **(1/4pt)**

For t = 0, we get : $0 = -10\sqrt{3} + 50\pi L + 5\sqrt{3}$. thus : L = 55 mH.

(1 ¼ pt)

B- 1) The phenomenon is current resonance **(1/2pt)**

2) Resonance, implies

$f_0 = \frac{1}{2\pi\sqrt{LC}}$, thus : L $\approx$ 55 mH. **(1pt)**

Third Exercise

A- 1) a) ${}^{137}_{55}Cs \rightarrow {}^{y}_{x}Ba + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$ **(1/2pt)**

$55 = x - 1 \Rightarrow x = 56$; $137 = y + 0 \Rightarrow y = 137$ **(1/2pt)**

b) ${}^{y}_{x}Ba^{*} \rightarrow {}^{y}_{x}Ba + \gamma$ **(1/2pt)**

2) a) $E = \Delta m \times c^2$. with $\Delta m = m_{before} - m_{after} = m_{Cs} - (m_{Ba} + m_{elecron}) = 1.15 \times 10^{-3}$ u

$\Delta m = 1.15\times10^{-3} \times 931.5$ MeV/c^2 = 1.0712 MeV/c^2.

E = 1.0712 MeV/c$^2 \times$ c^2 = 1.0712 MeV. **(1 ½ pt)**

b) E(liberated) = E(γ) + E(β^-) + K.E (Ba) + E(${}^{0}_{0}\bar{\nu}$)

1.0712 MeV = 0.557 + 0.514 + 0 + E (${}^{0}_{0}\bar{\nu}$) => E (${}^{0}_{0}\bar{\nu}$) = 0.0002 MeV. **(1pt)**

B) 1) $A = A_0 e^{-\lambda t}$, hence $t = \frac{1}{\lambda} \times \ln\frac{A_0}{A}$ =12 years.

Thus the date of fabrication of the counter is the beginning of the year 1992. **(1/2pt)**

2) Number of disintegrations during 1 h = n = A $\times$ t = $3.33.10^5 \times 3600 = 11988\times10^5$

(1/2 pt)

C- 1) Energy liberated during 1 hour = E_1 = E $\times$ number of disintegrations during 1 hour

h = E $\times$ n = $1.0712 \times 11988\times10^5$ MeV = 12841.5×10^5 MeV = 0.2055×10^{-3}J.

Energy absorbed by the student during 1 h = $E_2 = \frac{0.2055\times10^{-3}}{100} = 0.2055\times10^{-5}$J **(1 pt)**

2) $E_2 < 1.2\times10^{-4}$J => not any risk **(1/2pt)**

وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات	امتحانات الشهادة الثانوية العامة فرع علوم الحياة	دورة سنة 2005 الاستثنائية

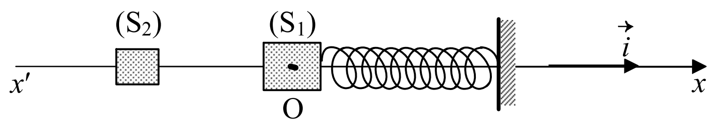
	مسابقة في مادة الفيزياء المدة: ساعتان	الاسم: الرقم:

This exam is formed of three exercises in 3 pages numbered from 1 to 3

The use of non-programmable calculators is allowed

First exercise (7 pts) Study of a mechanical oscillator

The object of this exercise is to determine the stiffness of the spring of a horizontal mechanical oscillator. This oscillator is formed of a solid (S_1) of mass M = 400 g and a spring of negligible mass and of stiffness k. The center of mass G of (S_1) may move on a horizontal straight axis x'Ox. The position of G is defined, at any instant t, by its abscissa $x = \overline{OG}$, O corresponding to the equilibrium position G_0 of G (figure).



A – Setting the oscillator in motion

(S_1) is initially at rest and G is at O. To set (S_1) in motion, a solid (S_2), of mass $m = \frac{M}{2}$, is launched towards (S_1) along the axis x'Ox . Just before collision, (S_2) was moving with the velocity $\vec{V}_2 = V_2\,\vec{i}$ ($V_2 = 0.75$ m/s). The collision between (S_1) and (S_2) being elastic, (S_2) rebounds along x'Ox.

Just after collision, (S_1) acquires the velocity $\overrightarrow{V_0} = V_0\,\vec{i}$.

1) What are the two physical quantities that remain conserved during this collision?
2) Write the equations that express the preceding conservations.
3) Deduce that $V_0 = 0.5$ m/s.

B- Energetic study of the oscillator

The graphical recordings show that the time equation of motion of G, after collision, may be written in the form:

$$x = X_m \sin\left(\sqrt{\frac{k}{M}}\,t\right) \quad (x \text{ in m ; t in s}) \text{ where } X_m \text{ is a positive constant.}$$

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

1) **a**- Write the expression of the elastic potential energy PE_e of the oscillator in terms of k , X_m , M, and t.
   b- Determine the expression of the kinetic energy KE of the oscillator in terms of k , M ,X_m ,and t.
   c- Find the expression of the mechanical energy ME of the system (oscillator, Earth) in terms of k and X_m.
   d- Deduce that (S_1) is not subjected to any force of friction during its motion.
2) **a**- Determine the value of ME.
   b- During the motion of (S_1), G oscillates between two extreme positions A and B, 20 cm apart.
   Determine the value of k.

Second exercise (6 ½ pts) Charge of a capacitor

The object of this exercise is to determine the capacitance of a capacitor and study the effect of certain physical quantities on the duration of its charging.

The circuit of figure (1) is formed of:

- an ideal generator delivering across its terminals an adjustable DC voltage $u_{MN} = u_g = E$;
- a resistor of adjustable resistance R ;
- a capacitor of capacitance C ;
- a switch K.

I- The value of E is adjusted at E = 10 V and that of R at R = 2 kΩ .

The capacitor being initially neutral, we close the switch at the instant $t_0 = 0$.

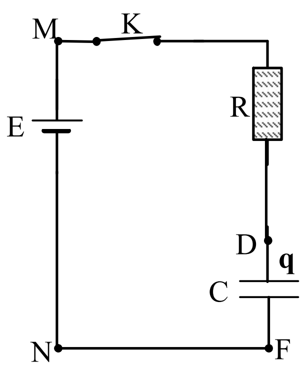


Figure 1

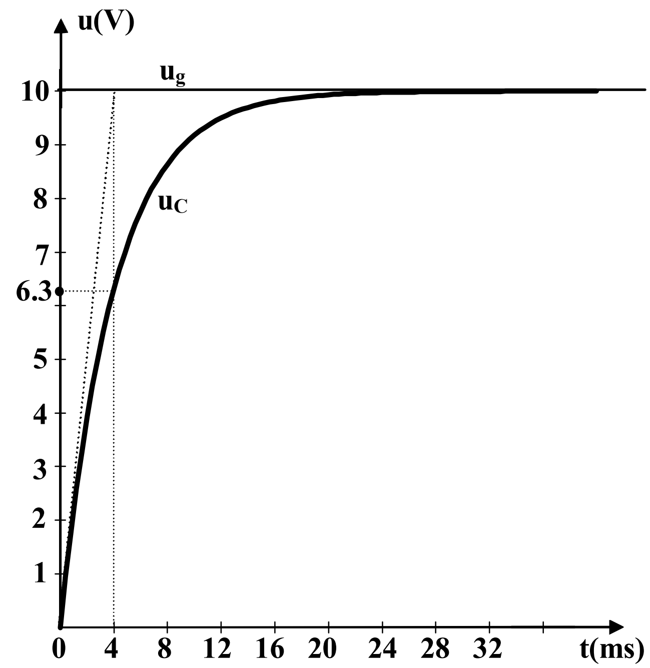


Figure 2

1) **a** –Derive the differential equation giving the variation of the voltage $u_{DF} = u_C$ across the capacitor as a function of time.

b- Verify that the solution of this differential equation is $u_C = E\,(1 - e^{\frac{-t}{RC}})$.

2) The voltages u_C and u_g are displayed using an oscilloscope (figure 2) .

a- Redraw the circuit of figure (1) showing the connections of the oscilloscope.

b- Give the maximum value of u_C.

3) One method to determine the value of C consists of determining the duration t_1 at the end of which the voltage u_C attains 63 % of its maximum value.

a- Show that t_1 is very close to the value of RC.

b- Using figure (2), determine the value of the capacitance C.

4) Another method allows us to determine C starting from the tangent at O to the curve $u_C = f(t)$ (fig.2)

a- Find the expression of $\frac{du_C}{dt}$,at O, in terms of E , R and C.

b- Show that the equation of this tangent to the curve is $u = \frac{E}{RC}t$.

c- Verify that this tangent intersects the asymptote to the curve at the point of abscissa $t_1 = RC$.

d- Determine then the value of the capacitance C of the capacitor.

II – The value of R is adjusted at R = 1 kΩ .

1) Trace , on the same system of axes, the shape of the curve u_C in the two following cases :

case (1) : E =10 V, $C = 2\times 10^{-6}$ F (curve 1)

case (2) : E = 5 V, $C = 2\times 10^{-6}$ F (curve 2)

Scale : on the axis of abscissas:1div ↔ 4 ms ; on the axis of ordinates :1 div ↔ 1 V .

2) Specify, with justification, which of the two physical quantities E or R affects the duration of charging of the capacitor.

Third exercise (6 ½ pts) Interaction radiation-matter

I- At the beginning of the 1880's, Balmer identified, in the emission spectrum of hydrogen, the four visible rays denoted by H_α, H_β, H_γ and H_δ.

In 1913, Bohr elaborated a theory about the structure of the atom and showed that we can associate, to the hydrogen atom, energy levels given by the formula:

$E_n = -\frac{E_0}{n^2}$ where E_0 is a positive constant expressed in eV and n is a whole non-zero number.

According to Bohr, each of the rays of Balmer series is characterized by its wavelength λ in air and the corresponding downward transition :

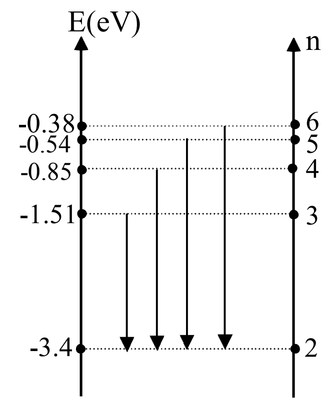
H_α (λ_α = 658 nm ; transition from n = 3 to n = 2) ;

H_β (λ_β = 487 nm ; transition from n = 4 to n = 2) ;

H_γ (λ_γ = 435 nm ; transition from n = 5 to n = 2) ;

H_δ (λ_δ = 412 nm ; transition from n = 6 to n = 2).

The corresponding energy diagram of this series is represented in the adjacent figure.



1) Determine, using the diagram, the value of E_0 in eV.

2) **a) Emission Spectrum**

i) Show, starting from the diagram, that the ray H_β corresponds to the emission of a photon of energy 2.55 eV.

ii) Verify that the value of the wavelength of the ray H_β is around 487 nm

b) Absorption spectrum

In order to obtain the absorption spectrum of the hydrogen atom, we illuminate hydrogen gas with white light. What do we observe in the absorption spectrum?

3) The hydrogen atom, being in its first excited state (n = 2), collides with a photon of energy 2.26 eV. This photon is not absorbed. Why?

II- A hydrogen lamp illuminates now a photosensitive metallic surface of threshold wavelength λ_o = 500 nm.

1) What are the visible radiations that may provoke photoelectric emission ? Why?

2) **a)** Determine the radiation that is able to extract an electron having the highest possible kinetic energy KE.

b) Calculate then KE .

III- The atomic line spectra and the phenomenon of photoelectric effect show evidence of a characteristic concerning the energy of an electromagnetic wave and the energetic exchange between matter and electromagnetic waves. Specify this characteristic.

Given:

- speed of light in vacuum $c = 3 \times 10^8$ m/s ;
- Planck's constant $h = 6.63 \times 10^{-34}$ J.s ;
- $1 \text{ eV} = 1.6 \times 10^{-19}$ J ;
- $1 \text{ nm} = 10^{-9}$ m.

مسابقة في مادة الفيزياء
المدة: ساعتان

الاسم:
الرقم:

This exam is formed of three exercises
The use of a non-programmable calculator is recommended

First exercise *(6 ½ pts)* ***Verification of Newton's second law***

A puck (S) of mass M = 100 g and of center of mass G, may slide along an inclined track that makes an angle α with the horizontal so that $\sin\alpha = 0.40$. Thus G moves along an axis $x'x$ parallel to the track as shown in figure (1). Take $g = 10\ m/s^2$.

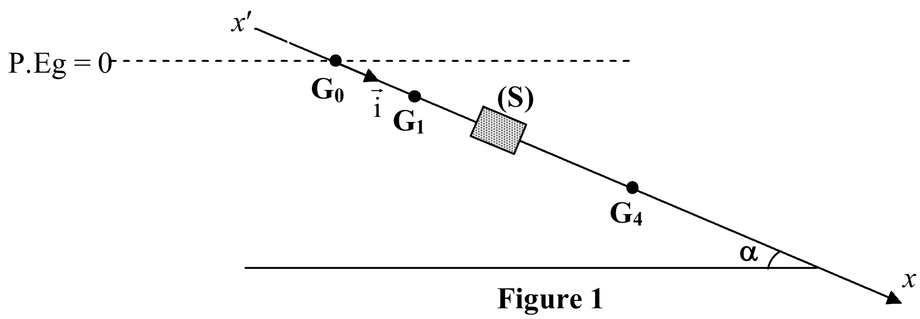


Figure 1

We release (S) without initial velocity at the instant $t_o = 0$ and at the end of each interval of time $\tau = 50$ ms, some positions G_o, G_1, G_2, …G_5 of G are recorded at the instants $t_o = 0$, t_1, t_2, … t_5 respectively.

The values of the abscissa x of G ($x = \overline{G_oG}$) are given in the table below.

t	0	τ	2τ	3τ	4τ	5τ
x (cm)	0	G_oG_1= 0.50	G_oG_2= 2.00	G_oG_3 = 4.50	G_oG_4 = 8.00	G_oG_5 =12.50

1) Verify that the speed of the puck at the instants $t_2 = 2\tau$ and $t_4 = 4\tau$ are $V_2 = 0.40$ m/s and $V_4 = 0.80$ m/s respectively.

2) a) Calculate the mechanical energy of the system (puck-Earth) at the instants t_0, t_2 and t_4 knowing that the horizontal plane through G_0 is taken as a gravitational potential energy reference.

b) Why can we suppose that the puck moves without friction along the rail?

3) Determine the variation in the linear momentum $\overrightarrow{\Delta P} = \overrightarrow{P_4} - \overrightarrow{P_2}$ of (S) during $\Delta t = t_4 - t_2$.

4) a) Name the forces acting on (S) during its motion.

b) Show that the resultant $\Sigma\vec{F}$ of these forces may be written as $\Sigma\vec{F} = (Mg \sin\alpha)\ \vec{i}$.

5) Assuming that Δt is very small, $\frac{\Delta\vec{P}}{\Delta t}$ may be considered equal to $\frac{d\vec{P}}{dt}$. Show that Newton's second law is verified between the instants t_2 and t_4.

Second exercise (6 ½ pts) Measurement of the speed of a bullet

In order to measure the speed of a bullet, a convenient setup is used. The principle of functioning of this setup is based on the charging of a capacitor.

A- Study of the charging of a capacitor

We are going to study the charging of a capacitor using a series circuit formed of a resistor of resistance R, a switch K and a capacitor of capacitance C initially neutral across the terminals of a generator of constant emf E and of negligible internal resistance (figure 1).

The switch K is closed at the instant $t_0 = 0$. The capacitor starts to charge. At the instant t , the circuit carries a current i and the armature A of the capacitor carries the charge q.

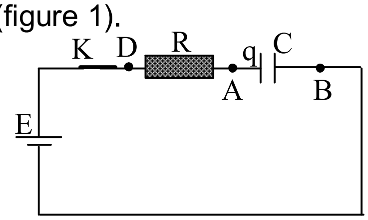


Figure 1

1) Applying the law of addition of voltages, determine the differential equation that describes the variation of the voltage $u_C = u_{AB}$ across the capacitor as a function of time.

2) **a)** Verify that $u_C = E\,(1 - e^{\frac{-t}{\tau}})$ is the solution of the differential equation where $\tau = RC$.

b) What does the time interval τ represent?

3) After what time would the steady state be practically attained?

B – Measurement of the speed of a bullet

The setup used to measure the speed V of a bullet is represented in figure 2.

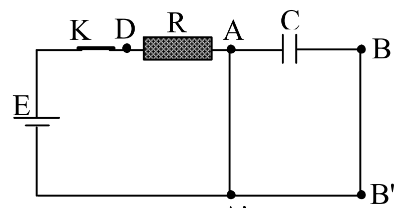


Figure 2

AA' and BB' are two thin parallel connecting wires lying in a vertical plane and are of negligible resistance . AA' and BB' are separated by a distance L.

Given: E = 100 V ; R = 1000 Ω ; C = 4 μF ; L = 1 m.

The capacitor being neutral, the switch K is closed.

1) **a)** The potential difference between A and A′ is zero. Why?

b) The charging of the capacitor did not start. Why?

2) K being closed , we shoot the bullet normally at AA' and BB' with a speed V (fig.3).

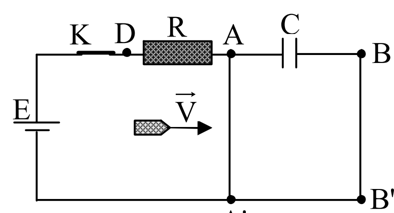


Figure 3

At the instant $t_0 = 0$, the bullet cuts the wire AA' and the capacitor starts to charge (fig.4).

The bullet continues its motion which is considered uniform rectilinear of the same speed V.

At the instant t_1, the bullet cuts the wire BB' and the phenomenon of charging stops. The voltage across the capacitor is then 45.7 V.

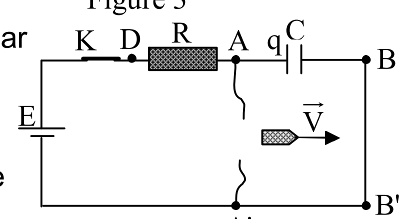


Figure 4

a) Taking into consideration the study in part A, determine the time interval t_1 taken by the bullet to cover the distance L.

b) Calculate V.

3) In order to measure precisely the value of V , the distance L between AA' and BB' must not exceed a maximum value L_{max}. Determine the value of L_{max} .

Third exercise (7 pts) Measurement of the age of Earth

One of the questions that preoccupied man long ago since he started to explore the universe was the age of Earth. As from 1905, Rutherford proposed a measurement of the age of minerals through radioactivity.

In 1956, Clair Paterson used the method (uranium - lead) to measure the age of a meteorite assuming that it originates from a planet that is formed approximately at the same time as that of Earth.

I – A radioactive family of uranium $^{238}_{92}U$

Uranium 238, of radioactive period T= 4.5×10^{9} y (year) is at the origin of a radioactive family leading finally to the stable lead isotope $^{206}_{82}Pb$.

Each of these successive disintegrations is accompanied with the emission of an α particle or a β^- particle.

The diagram (Z, N) gives all the radioactive nuclei originating from the uranium $^{238}_{92}U$ leading to the stable isotope $^{206}_{82}Pb$. (**page 4**)

The tables (**page 4**) give the radioactive period of each nuclide.

1) In the first disintegration, a uranium nucleus $^{238}_{92}U$ gives thorium nucleus $^{234}_{90}Th$ and a particle denoted by $^{A_1}_{Z_1}X$.

a) Write the equation of this disintegration and calculate the values of A_1 and Z_1.

b) Specify the type of radioactivity corresponding to this transformation.

2) In the second disintegration, the thorium nucleus $^{234}_{90}Th$ undergoes a β^- decay. The daughter nucleus is the protactinium $^{A_2}_{Z_2}Pa$. Calculate A_2 and Z_2.

3) a) Referring to the diagram, tell how many α particles and how many β^- particles are emitted when the uranium nucleus $^{238}_{92}U$ is transformed into lead nucleus $^{206}_{82}Pb$.

b) Write the overall nuclear equation of the decay of uranium 238 into lead 206.

4) Using the diagram (Z,N) of the figure and the tables, tell why after few billions of years we can neglect the presence of the intermediary nuclei among the products of the disintegration uranium-lead.

II- The age of Earth

We have studied a sample of a meteorite whose age is equal to that of Earth. At the instant t , the sample studied contains 1g of uranium 238 and 0.88g of lead 206.

We suppose that at the instant of its formation t_0 = 0, the meteorite does not contain any atom of lead.

Numerical data: molar mass of uranium: 238 g/mol; molar mass of lead: 206 g/mol; Avogadro's number: N_A= 6.02x 10^{23} /mol.

1) Calculate, at the instant t :

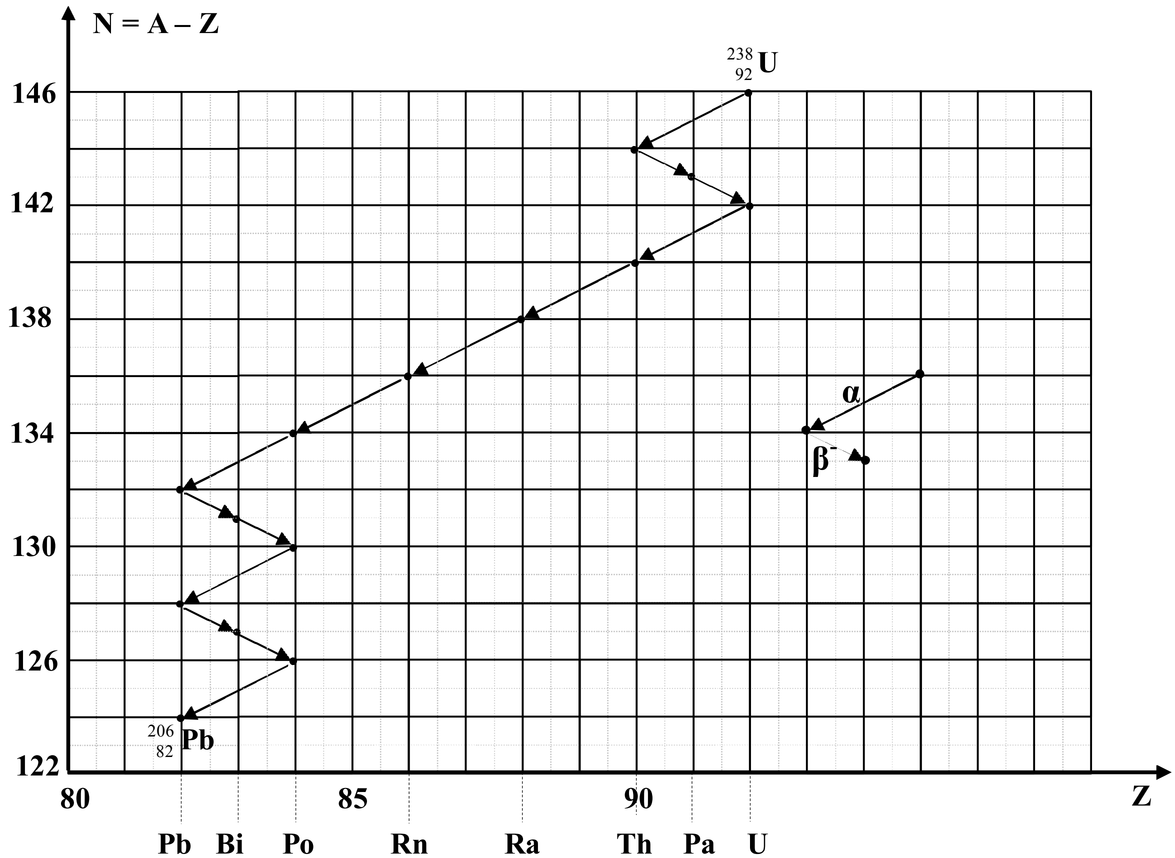
a) the number of uranium 238 nuclei , denoted by $N_U(t)$, present now in the sample;

b) the number of lead 206 nuclei , denoted by $N_{Pb}(t)$, present now in the sample.

2) Deduce the number of uranium 238 nuclei N_U (0), present in the sample at the instant t_0 = 0.

3) Give the expression of $N_U(t)$ as a function of $N_U(0)$, t, and T.

4) Deduce the age of Earth at the instant t.



Nucleus	$^{238}_{92}U$	$^{234}_{90}Th$	$^{234}_{91}Pa$	$^{234}_{92}U$	$^{230}_{90}Th$	$^{226}_{88}Ra$	$^{222}_{86}Rn$
Radioactive period	4.5×10^9 y	24 d	6.7 h	2.5×10^5 y	7.5×10^3 y	1.6×10^3 y	3.8 d

Nucleus	$^{218}_{84}Po$	$^{214}_{82}Pb$	$^{214}_{83}Bi$	$^{214}_{84}Po$	$^{210}_{82}Pb$	$^{210}_{83}Bi$	$^{210}_{84}Po$
Radioactive period	3.1 min	27 min	20 min	1.6×10^{-4}s	22 y	5d	138 d

Solution

First exercise: (6 ½ pts)

1) $V_2 = \frac{G_1G_3}{2\tau} = \frac{G_0G_3 - G_0G_1}{2\tau} = \frac{(4.5-0.5)\times10^{-2}}{0.1} = 0.4$ m/s. **($\frac{1}{2}$ pt)**

$V_4 = \frac{G_3G_5}{2\tau} = \frac{G_0G_5 - G_0G_3}{2\tau} = \frac{(12.5-4.5)\times10^{-2}}{0.1} = 0.8$ m/s. **($\frac{1}{2}$ pt)**

2) a) M.E = K.E + $P.E_g$;

$M.E_0 = K.E_0 + PE_{g0} = 0 + 0 = 0$

$M.E_2 = K.E_2 + PE_{g2} = \frac{1}{2}\ M(V_2)^2 - Mgh_2$;

$h_2 = G_0G_2\times\sin\alpha = 2\times0.4 = 0.8$ cm = 0.008 m $\Rightarrow M.E_2 =$ 0 J.

$M.E_4 = K.E_4 + PE_{g4} = \frac{1}{2}\ M(V_4)^2 - Mgh_4$;

$h_4 = G_0G_4\times\sin\alpha = 8\times0.4 = 3.2$ cm = 0.032 m $\Rightarrow M.E_4 =$ 0 J. **(2 pts)**

b) $M.E_0 = M.E_2 = M.E_4$ $\Rightarrow$ the mechanical energy is conserved during motion $\Rightarrow$ No friction. **($\frac{1}{2}$ pt)**

3) $\Delta\vec{P} = \vec{P_4} - \vec{P_2} = M\,(V_4\vec{i}\ - V_2\vec{i}) = 0.04\vec{i}$ **($\frac{3}{4}$ pt)**

4) a) The forces acting on (S) :

The weight $\vec{W}$ of (S) and the normal reaction $\vec{N}$ of the path **($\frac{1}{4}$ pt)**

b) $\Sigma\vec{F} = \vec{W} + \vec{N} = \vec{W_1} + \vec{W_2} + \vec{N}$

where : $\vec{W_1} = Mg\sin\alpha\,\vec{i}$, $\vec{W_2} = -Mg\cos\alpha\,\vec{j}$,

$\vec{N} = N\vec{j}$; $\vec{W_2} + \vec{N} = \vec{0}$ (no motion along y'y)

$\Rightarrow \Sigma\vec{F} = \vec{W_1} = mg\sin\alpha\,\vec{i}$ **(1 pt)**

5) The 2nd Law of is given by : $\Sigma\vec{F} = \frac{d\vec{P}}{dt} = \frac{\Delta\vec{P}}{\Delta t}$.

We have: $\Sigma\vec{F} = mg\sin\alpha\,\vec{i} = 0.4\vec{i}$ and $\frac{\Delta\vec{P}}{\Delta t} = \frac{0.04\vec{i}}{0.1} = 0.4\ \vec{i}$

$\Rightarrow$ The 2nd Law of Newton is thus verified. **(1pt)**

<u>Second exercise</u> (6 ½ pts)

A- 1) $E = u_R + u_C \Rightarrow E = Ri + u_C = R\frac{dq}{dt} + u_C = RC\frac{du_C}{dt} + u_C$ **(1 pt)**

2) a) $\frac{du_C}{dt} = \frac{E}{RC}e^{\frac{-t}{\tau}} \Rightarrow E = RC \Rightarrow \frac{E}{RC}e^{\frac{-t}{\tau}} + E\,(1 - e^{\frac{-t}{\tau}}) = E$ **(1 pt)**

b) τ is the time taken for u_c = 63% E. **($\frac{1}{2}$ pt)**

3) The steady state is reached for t = 5RC. **($\frac{1}{2}$ pt)**

B - 1) a) because AA' is a connecting wire of negligible resistance. **($\frac{1}{4}$ pt)**

b) $u_C = u_{AA'} = 0$ **($\frac{1}{4}$ pt)**

2) a) We have $u_C = E\,(1 - e^{\frac{-t}{\tau}})$. We can write :

$1 - e^{\frac{-t}{\tau}} = \frac{u_C}{E} \Rightarrow e^{\frac{-t}{\tau}} = 1 - \frac{u_C}{E} \Rightarrow -\frac{t_1}{RC} = \ln(1 - \frac{u_C}{E})$

$\Rightarrow t_1 = -RC \times \ln(1 - \frac{u_C}{E}) = -0.004 \times \ln(1 - \frac{45.7}{100}) = 2.44$ ms.

t_1 is the time of charging which is the same as the time taken by the bullet **(1$\frac{1}{2}$ pt)**

b) $V = \frac{L}{t_1} = \frac{1}{2.44 \times 10^{-3}} = 410$ m /s. **($\frac{1}{2}$ pt)**

3) Because if this time exceeds 5RC, the steady state is attained and will no more vary. Thus $t \leq 5RC \Rightarrow \frac{L}{V} \leq 5RC$

$\Rightarrow L \leq 5RCV \Rightarrow L \leq 8.02$ m $\Rightarrow L_{max} = 8.02$ m. **(1 pt)**

Third exercice : (7 pts)

I-1) a) ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{A_1}_{Z_1}X$

$238 = 234 + A_1 \Rightarrow A_1 = 4$.

$92 = 90 + Z_1 \Rightarrow Z_1 = 2$ **(1pt)**

b) nucleus ${}^{A_1}_{Z_1}X$ is Helium $\Rightarrow$ The type of the radioactivity is α. **($\frac{1}{2}$ pt)**

2) ${}^{234}_{90}Th \rightarrow {}^{0}_{-1}e + {}^{A_2}_{Z_2}Pa$

$234 = 0 + A_2 \Rightarrow A_2 = 234$

$90 = -1 + Z_2 \Rightarrow Z_2 = 91$ **(1pt)**

3) **a)** There are 8 particles of α and 6 particles of β^-. **($\frac{3}{4}$ pt)**

b) ${}^{238}_{92}U \rightarrow {}^{206}_{82}Pb + 8\,{}^{4}_{2}He + 6\,{}^{0}_{-1}e$ **($\frac{1}{2}$ pt)**

4) The radioactive period of each nucleus of the family is too small as compared to that of the nucleus of ${}^{238}_{92}U$. **($\frac{1}{4}$ pt)**

II - 1) a) $Nu(t) = \dfrac{N_A \times 1}{238} = 252941 \times 10^{16}$ nuclei **($\frac{1}{2}$ pt)**

b) $N_{Pb}(t) = \dfrac{N_A \times 0.88}{206} = 257165 \times 10^{16}$ nuclei **($\frac{1}{2}$ pt)**

2) $N_U(0) = N_U(t) + N_{Pb}(t) = 510106 \times 10^{16}$ nuclei **($\frac{3}{4}$ pt)**

3) $N_U(t) = N_U(0) \times e^{\frac{-0.693t}{T}}$ **($\frac{1}{2}$ pt)**

4) $t = \dfrac{T}{0.693} \times \ln \dfrac{N_U(0)}{N_U(t)} = 4.55 \times 10^9$ years.

The age of the Earth is 4.55×10^9 years **($\frac{3}{4}$ pt)**

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المديرية العامة للتربية
دائرة الامتحانات

امتحانات الشهادة الثانوية العامة
فرع علوم الحياة

دورة سنة 2006 الاكمالية الاستثنائية

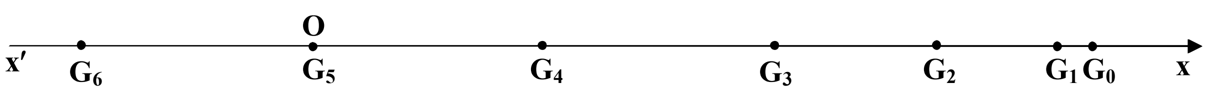
مسابقة في مادة الفيزياء
المدة: ساعتان

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 $\tau = 20$ 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:
$x = X_m \sin(\omega_0 t + \varphi)$ where X_m, ω_0 and φ 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: $i = I_m \sin(\omega t+\varphi)$

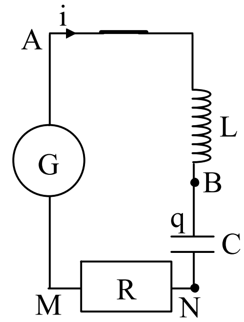


Figure 1

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:

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

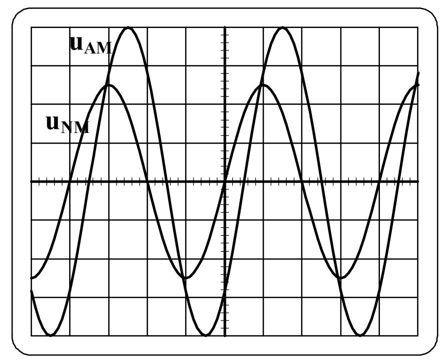


Figure 2

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.

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).

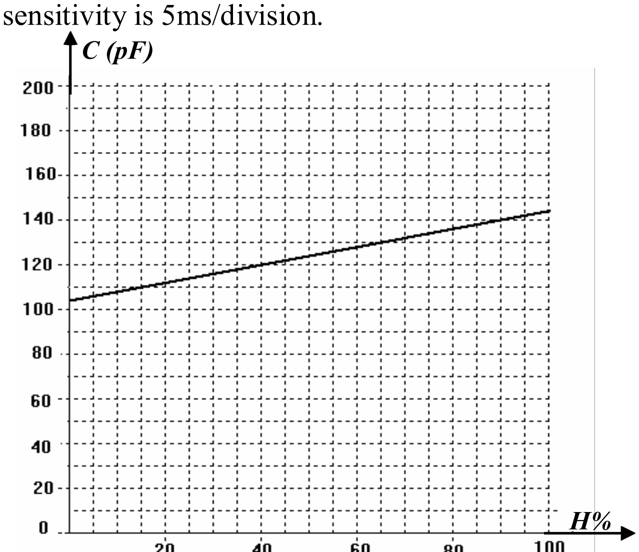
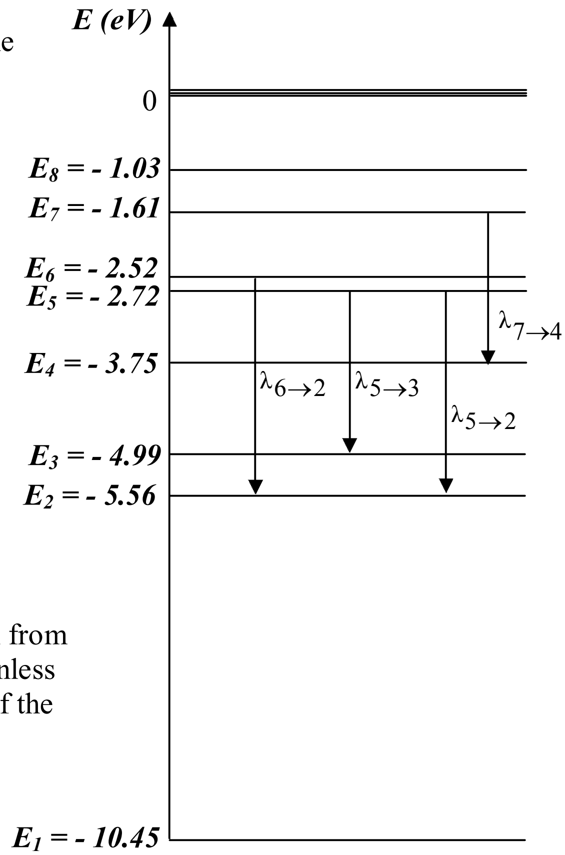


Figure 3

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.

***Third exercise**: (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.

Given:
Planck's constant h = 6.62×10^{-34} J.s;
speed of light in vacuum : c = 3×10^{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.

Solution

<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

$\Rightarrow \frac{dE_m}{dt} = 0 = mx'x'' + kxx' \Rightarrow x'' + \frac{k}{m}x = 0.$**(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 :

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

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

(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). $\Rightarrow ½\ m (V_{max})^2 = ½\ mv^2 + ½\ kx^2 \Rightarrow (V_{max})^2 = v^2 + \omega_0^2 x^2$ **(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 : $\omega_0 = 15.44$ 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 $q = C\,u_C$ $\Rightarrow i = C du_C / dt$. **(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- $u_{AB} = Ldi/dt = L\omega I_m \cos(\omega t + \varphi)$ **(1/2pt)**

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

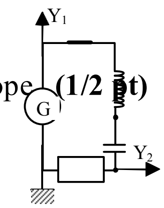
$\Rightarrow U_m \sin\omega t =$

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

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

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

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

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

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

b- At current resonance : $\varphi = 0 \Rightarrow \frac{1}{C\omega} - L\omega = 0 \Rightarrow 4$

$\pi^2 LCf_1^{\,2} = 1$ **(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:

$E = \frac{hc}{\lambda} = 9.63 \times 10^{-19}$ 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 $\Rightarrow$ $\lambda_2 = 1.188 \times 10^{-7}$ 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)**

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فرع علوم الحياة

دورة سنة 2007 العادية

مسابقة في مادة الفيزياء المدة: ساعتان	الاسم: الرقم:

This exam is formed of three exercises in four pages numbered from 1 to 4.

<u>The use of non-programmable calculator is recommended</u>

<u>First exercise</u> (*7 ½ pts*) **Mechanical Oscillator**

Consider a mechanical oscillator formed of a solid (S) of mass m and whose center of inertia is G and a spring of negligible mass of un-jointed turns whose stiffness is k.
(S) may slide on a horizontal rail; the position of G on the horizontal axis $\overrightarrow{Ox}$ is defined relative to the origin O, the position of G when (S) is in the equilibrium position (Fig.1).

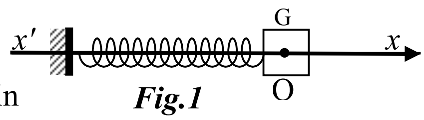

Fig.1

An apparatus is used to record the variations of the abscissa x of G and the algebraic measure v of its velocity as a function of time.
The horizontal plane through G is taken as a gravitational potential energy reference.
The object of this exercise is to compare the values of certain physical quantities associated with the motion of the oscillator in two situations.

A – First situation

The solid performs oscillations and the mechanical energy M.E of the system (oscillator, Earth) keeps a constant value M.E = 64×10^{-3} J.
The recording apparatus gives the curves represented in figures (2) and (3).

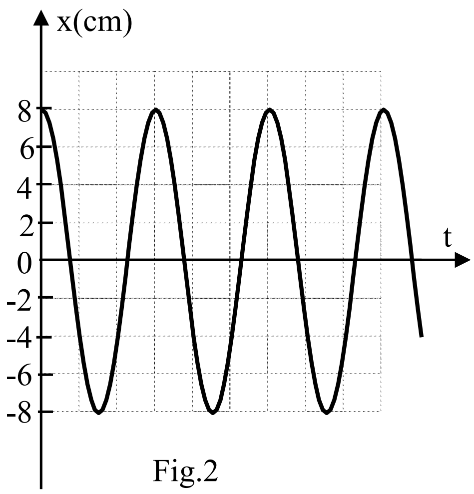

Fig.2

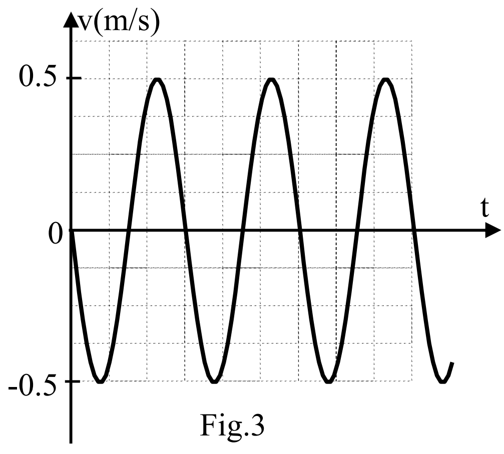

Fig.3

1) Refer to figures (2) and (3).

a) Indicate the type of oscillations of (S).

b) Specify : ***i)*** the abscissa x_0 and the value v_0 of the velocity at the instant $t_0 = 0$;

ii) the value of X_m, the amplitude of the oscillations and the maximum value V_m of the velocity;

iii) the direction of motion of G when it passes through the origin O for the first time.

2) Applying the principle of conservation of mechanical energy, show that:

a) the stiffness of the spring has a value k = 20 N/m ;

b) the mass of (S) has a value m = 512 g.

3) ***a)*** Write the expression of the mechanical energy of the system (oscillator, Earth) in terms of m, v, k and x.

b) Determine the second order differential equation in x which describes the motion of G.

c) Deduce the expression of the proper angular frequency ω_0 in terms of k and m.

d) The solution of the second order differential equation in this situation is $x = X_m \cos(\omega_0 t + \varphi)$ where φ is a constant. Determine the value of φ.

B- Second situation

The solid (S), now shifted by a distance x_{o1} from its equilibrium position, is launched, at the instant $t_o = 0$, in the positive direction with an initial velocity of magnitude v_{o1}. The apparatus thus records the variations of the abscissa x as a function of time (fig.4)

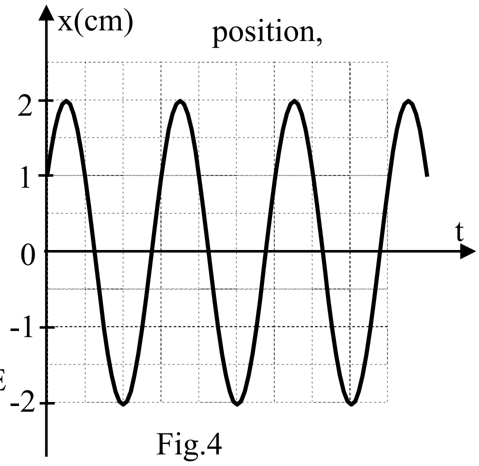

Fig.4

1) Referring to figure 4 :

a) give the value of x_{o1} of G and that of the amplitude X_{m1} of motion.

b) show that the mechanical energy $M.E_1$ of the system (oscillator, Earth) does not vary with time;

c) show that the value of $M.E_1$ is different from that of M.E given in the first situation.

2) Calculate the value of the elastic potential energy of the oscillator at $t_0 = 0$ and determine the value of v_{o1}.

3) The value of ω_0 is the same in both situations. Why?

4) The solution of the second order differential equation in this situation is $x_1 = X_{m1} \cos(\omega_0 t + \varphi_1)$. Show that the value of φ_1 is different from that of φ.

<u>Second exercise</u> (6 ½ *pts*) Usage of a Coil

A-First experiment

A bar magnet may be displaced along the axis of a coil whose terminals A and C are connected to a resistor of resistance R.

We approach the north pole of the magnet towards the face A of the coil (Fig.1). An induced current i is carried by the circuit.

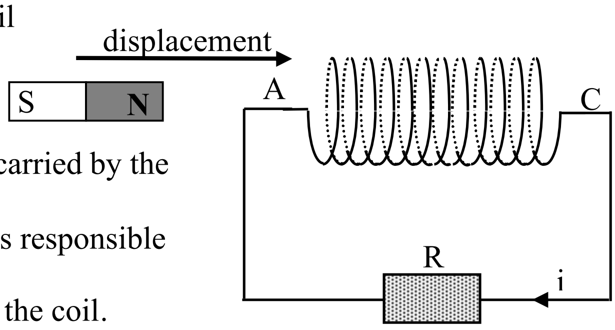

Fig.1

1) Give the name of the physical phenomenon that is responsible for the passage of this current.

2) Give, with justification, the name of each face of the coil.

3) The induced current passes from C to A through the resistor. Why?

4) Determine the sign of the voltage u_{AC}.

B- Second experiment

A coil of inductance L = 0.01H and of negligible resistance is connected in series with a resistor of resistance R across a generator G (Fig.2). The coil thus carries a current i that varies with time as shown in figure 3.

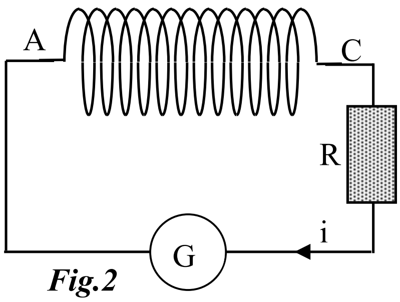

Fig.2

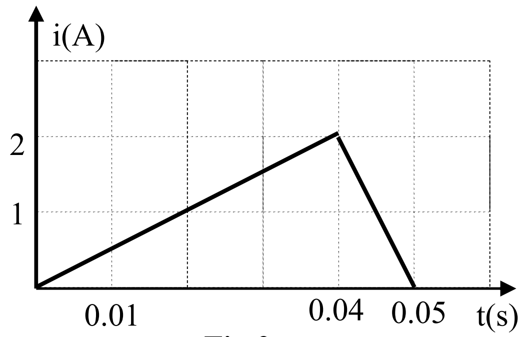

Fig.3

1) Give the name of the physical phenomenon that takes place in the coil.
2) Determine the voltage u_{AC} in each of the two intervals: [0; 0.04s] and [0.04s; 0.05s].

C- Third experiment

1) The Fig. 4 represents the diagram of a loaded transformer. The generator delivers an alternating sinusoidal voltage of frequency f .The coil (1) carries an alternating sinusoidal current i_1 of frequency f. The coil (2) thus carries an alternating sinusoidal current i_2 having the same frequency f.
Explain the existence of the current in coil (2).

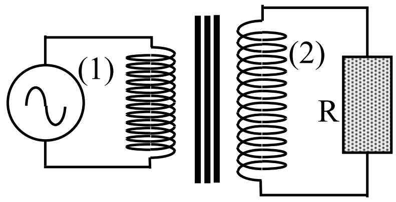

Fig.4

2) The object of this part is to show evidence of the role of a transformer in the transmission of electric energy.
An electric generator G delivers a power P = 20 kW under an alternating sinusoidal voltage of effective value U.
A transmission line of total resistance r = 1Ω feeds an electric installation (B).
Let I be the effective current that passes in the line. The power factor of the system formed of the line and the installation is cosφ = 0.95 .

a) Give the expression of the power P in terms of U, I and cosφ.

b) i) Give the expression of the power P′ lost in the line due to Joule's effect in terms of P, r, cosφ and U.

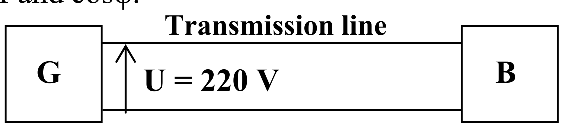

Fig.5

ii) Calculate P′ in the case when U = 220 V (Fig.5)

iii) A transformer, connected across the generator, raises the effective value of the voltage across the transmission line . The transmission of the same power P through the line thus takes place under the new effective voltage $U = 10^4$ V (Fig.6).
Calculate the new value of P′ .

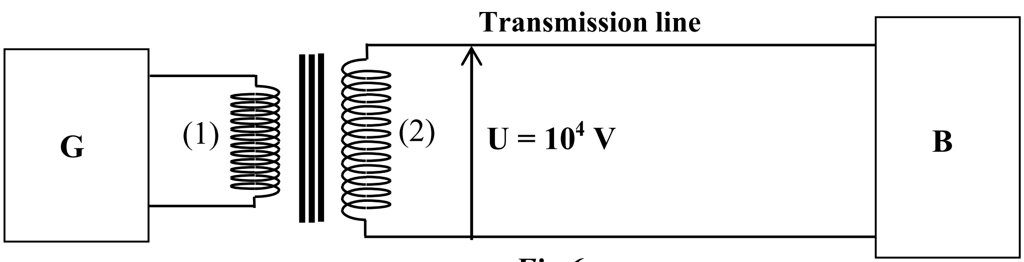

Fig.6

c) Draw a conclusion about the importance of the usage of the transformer in the transmission of electric energy over large distances.

3

Third exercise (6 pts) Nuclear Fusion

Given: masses of the nuclei: ${}^{2}_{1}H$: 2.0134 u ; ${}^{3}_{1}H$: 3.0160 u ; ${}^{4}_{2}He$: 4.0015 u ;

${}^{235}_{92}U$:235.12 u ; ${}^{1}_{0}n$: 1.0087 u .

1 u = 931.5 MeV/c^2 = 1.66×10^{-27} kg ; 1 MeV = 1.6×10^{-13}J.

The combustion of 1 ton of fuel oil liberates an energy of 42×10^9J .

The controlled nuclear fusion, if this technique is well mastered, provides enormous energetic possibilities. Nowadays, all the studies, in research centers, focus on the fusion reaction between deuterium nucleus (${}^{2}_{1}H$) and tritium nucleus (${}^{3}_{1}H$) according to the following equation:

$${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$$

The deuterium is abundant in nature; water is a huge reserve of this gas. The tritium is easily obtained by bombarding lithium (that exists in large quantities in minerals) by neutrons.

A - Advantages of the fusion of deuterium - tritium

1) Show that the mass defect in this reaction is: Δm = 0.0192 u.
2) Calculate, in MeV then in J, the energy liberated by this reaction.
3) Show that the energy liberated by the fusion of 1 g of a mixture formed of equal numbers of deuterium nuclei and tritium nuclei is 3.42×10^{11}J.
4) Calculate, in J, the energy liberated by the combustion of 1 g of fuel oil.
5) The fission of a uranium 235 nucleus gives, on the average, an energy of 200 MeV. Determine, in J, the energy liberated by the fission of 1 g of uranium 235.
6) Give three reasons rendering the controlled fusion a source of energy better than that of fuel oil and nuclear fission.

B - Does the fusion reaction of deuterium - tritium take place in the Sun?

The two nuclei of deuterium and tritium repel each other. In order to fuse, they must collide with very high velocities, each of the two nuclei having, before collision, a kinetic energy whose minimum value is K.E = 0.35 MeV.

1) Why do the two deuterium and tritium nuclei repel?
2) The kinetic energy of a nucleus is proportional to the temperature T of the medium in which it exists: K.E = 1.3×10^{-4} T (K.E in eV and T in K). Calculate the minimum temperature T_1 of the medium convenient for the two nuclei to undergo fusion.
3) Such fusion reaction takes place in the core of certain stars. The temperature in the core of the Sun being $T_2 = 15\times 10^6$ K, show that this fusion reaction does not occur in the core of the Sun.

Solution

First exercise (7 ½ pts)

A- 1) a) The oscillations are **free and un-damped**. **(1/4 pt)**

b) i) At t = 0 : $x_0 = 8$ cm and $v_0 = 0$. **(1/2 pt)**

ii) $X_m = 8$ cm ; $V_m = 0.5$ m/s. **(1/2 pt)**

iii) when passes through O for the first time, v < 0

$\Rightarrow$ (S) is displaced in the negative direction. **(1/4 pt)**

2- a) $M.E = ½\, k(X_m)^2 \Rightarrow k = 20$ N/m. **(1/2 pt)**

b) $M.E = ½\, m\, (V_m)^2 \Rightarrow m = 512$ g. **(1/2 pt)**

3- a) $M.E = ½\, m(v)^2 + ½k\,(x)^2$. **(1/2 pt)**

b) $M.E = cte \Rightarrow (M.E)' = 0 \Rightarrow mvv' + Kxv = 0$

$\Rightarrow x'' + \dfrac{K}{m}\, x = 0.$ **(1/2 pt)**

c) The differential equation has the form : $x'' + (\omega_0)^2 x = 0$

$\Rightarrow \quad (\omega_0)^2 = \dfrac{k}{m} \Rightarrow \omega_0 = \sqrt{\dfrac{k}{m}}$. **(1/2 pt)**

d) for t = 0 we have : $x = x_0 = X_m \cos\varphi \Rightarrow \cos\varphi = 1 \Rightarrow \varphi = 0$. **(1/2 pt)**

B- 1)

a) $x_{01} = 1$ cm ; $X_{max1} = 2$ cm. **(1/2 pt)**

b) because the amplitude of of the motion X_{m1} does not decrease with time. **(1/4 pt)**

c) $M.E = ½\, k(X_m)^2$; $X_{m1} = 2$ cm and $X_m = 8$ cm $\Rightarrow M.E_1 \neq M.E$ **(1/2 pt)**

2) $P.E_0 = ½\, k(x_{01})^2 = 10^{-3}$J **(1/4 pt);**

$½\, k(x_{01})^2 + ½\, m(v_{01})^2 = ½\, k(X_{m1})^2 = 4 \times 10^{-3}\text{J} \Rightarrow v_0 = 0.108$ m/s. **(3/4 pt)**

3) since the angular frequency does not depend on the initial conditions, it depends on m and k only **(1/4 pt)**

4) In situation A, we have : $\cos\varphi = \dfrac{x_0}{X_m} = \dfrac{8}{8} = 1 \quad (\varphi = 0)$

In situation B , we have : $\cos\varphi_1 = \dfrac{x_{01}}{X_{m1}} = \dfrac{1}{2} \quad (\varphi_1 = -\dfrac{\pi}{3}\text{rad})$

$\Rightarrow \varphi_1 \neq \varphi$ **(1/2pt)**

Second exercise (6 ½ pts)

A- 1) Electromagnetic induction. **(1/4 pt)**

2) In order to oppose , by repulsion the approach of the N-pole of the magnet. (Lenz's law), A is the North face , B is the South face. **(1/2pt)**

3) The induced magnetic field $\vec{B_i}$ opposes the increase of $\vec{B}$ of the magnet thus it has a sign opposite to that of $\vec{B}$, the induced current thus passes from C to a through the resistor **(1/2 pt)**

4) A is the negative pole of the equivalent generator $\Rightarrow u_{AC} < 0$. **(1/2pt)**

B- 1) Self-induction. **(1/4pt)**

2) $u_{AC} = L\frac{di}{dt}$ **(1/4 pt)**

for $0 \leq t \leq 0.040$ s, $\frac{di}{dt} = \frac{2}{0.04} = 50 A/s \Rightarrow u_{AC} = 0.01 \times 50 = 0.5 V.$ **(3/4pt)**

for $0.040 \leq t \leq 0.050$ s, $\frac{di}{dt} = -\frac{2}{0.01} = -200 A/s \Rightarrow$

$u_{AC} = 0.01 \times -200 = -2V.$ **(3/4pt)**

C-1) i_1 is variable $\Rightarrow$ A variable magnetic field $\vec{B}$ is produced in the primary.The magnitude of $\vec{B}$ has the same value in the primary and in the secondary at any instant: The magnetic flux in the secondary is variable

=> the secondary is the seat of induced e.m.f,

the secondary being closed, an induced i_2 current will pass in it . **(1/2 pt)**

2) a) $P = UI\cos\varphi$. **(1/4 pt)**

b) i) $P' = rI^2 = r\left(\frac{P}{U\cos\varphi}\right)^2$. **(1/2 pt)**

ii) $P' = \frac{1 \times 4 \times 10^8}{0.9025 \times U^2} = \frac{4.4 \times 10^8}{U^2}$. if U = 220 V,

we get : $P' = 9 \times 10^3$ W **(1/2 pt)**

iii) if $U = 10^4$ V, we get a : P' = 4.4 W. **(1/2pt)**

c) The problem of the heat losses due to Joule's effect , has a solution in using high voltage in the transmission of electric energy thus we use step-up transformers. **(1/2 pt)**

3) $T_2 < T_1$ (180 times less) => The fusion deuterium- tritium cannot take place in the core of the Sun. **(1/2pt)**

Third exercise (6 pts)

A-

1) $\Delta m = m({}^2_1H) + m({}^3_1H) - [m({}^4_2H_e) + m({}^1_0n)] =$ 2,0134 +3.0160 – [4.0015 +1.0087] = 0.0192 u **(1pt)**

2) The energy liberated is due to the mass defect Δm. $E = \Delta m \times c^2 = 0.0192 \times 931.5 =$ 17.88 MeV
The energy liberated by the fusion of two nuclei is E = 17.88 MeV = 28.6×10^{-13}J. **(1pt)**

3) Each fusion requires 2.0134 + 3.0160 = 5.0294 u= 8.35×10^{-24}g of the mixture and liberates an energy E = 28.6×10^{-13}J. 1 g of the mixture liberates $E' = \frac{28.6 \times 10^{-13}}{8.35 \times 10^{-24}} = 3.42 \times 10^{11}$ J **(1pt)**

4) The energy liberated by the combustion of 1 g of fuel oil is : $4.2.10^4$ **J** **(1/4 pt)**

5) The mass of one uranium 235 nucleus is 235.12 u = 3.9×10^{-22} g .
The energy liberated by the fission of 1 g of uranium 235 is : $\frac{3.2 \times 10^{-11}}{3.9 \times 10^{-22}} = 8.2 \times 10^{10}$ J **(1/2 pt)**

6) - the nuclear fusion is more energetic
- the nuclear fusion is not polluting
- The raw material is obtained easier an dis cheaper **(3/4pt)**

B - 1) Because the two nuclei are both positively charged. **(1/4pt)**

2) K.E > 0.35×10^6eV => 1.3×10^{-4} T > 0.35×10^6 => $T_{min} = T_1 = 2.7 \times 10^9$ K. **(3/4pt)**

3) $T_2 < T_1$ (180 times less) => The fusion deuterium- tritium cannot take place in the core of the Sun. **(1/2pt)**

مسابقة في مادة الفيزياء
المدة: ساعتان

الاسم:
الرقم:

This exam is formed of three exercises in 3 pages

<u>The use of non-programmable calculators is recommended</u>

<u>First exercise</u> (7pts) Mechanical interaction

The object of this exercise is to study some physical quantities of a system whose parts are in mechanical interaction.

For that, we use two pucks (A) and (B), of respective masses $m_A=100g$ and $m_B = 120g$, that may move without friction on a horizontal table. Each puck is surrounded by an elastic steel shock ring of negligible mass. The two pucks are connected by a massless and inextensible taut thread thus compressing the steel shock rings. The system (S) thus formed is at rest. (Figure 1)

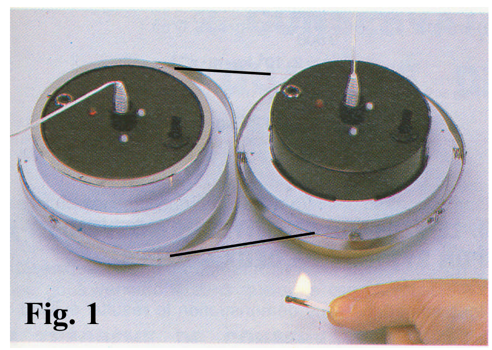

Fig. 1

We burn the thread; the shock rings stretch and the pucks repel each other. The system (S) thus formed of the two pucks and the shock rings is said to "*explode*".

The positions of the center of mass of each puck are registered at successive instants separated by a constant time interval $\tau = 50$ ms.

Figure (2) represents, on the axis x'x, the dot-prints of the positions of the centers of masses G_A and G_B of the two pucks after the «explosion».

Fig. 2

1) Using the document of figure (2) , show that , after explosion:
   a- The motion of each puck is uniform;
   b- The speeds of (A) and (B) are $V_A = 1.2$ m/s and $V_B = 1$ m/s respectively.

2) Verify the conservation of the linear momentum of the system (S) during explosion.

3) Applying Newton's second law $\frac{d\vec{P}}{dt} = \sum \overrightarrow{F_{ext}}$ on each puck and assuming that the time interval of the explosion $\Delta t = 0.05$ s is so small that $\frac{\Delta \vec{P}}{\Delta t}$ has the same value as $\frac{d\vec{P}}{dt}$,
   a- Determine the forces $\vec{F}_{A\to B}$ and $\vec{F}_{B\to A}$ exerted respectively by (A) on (B) and by (B) on (A).
   b- Verify the principle of interaction.

4) The system (S) possesses a certain energy before the explosion.
   a- Specify the part of (S) storing this energy.
   b- In what form is this energy stored?
   c- Determine the value of this energy.

<u>Second exercise</u> (6 ½ pts) Charging and discharging of a capacitor

The object of this exercise is to study the functioning of an apparatus that allows the illumination and the putting off automatically of a lamp at the end of an adjustable time interval t_1.

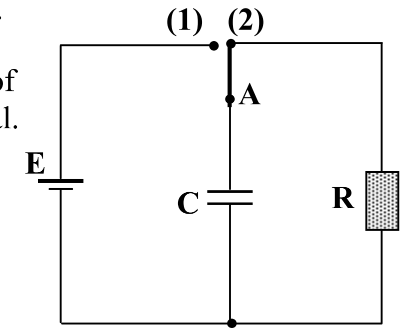

Figure 1

A-Principle of functioning of the apparatus

Consider a source of DC voltage of value E, a push-button switch, a resistor of resistance R and a capacitor of adjustable capacitance C that is initially neutral. We connect up the circuit represented in figure 1.

***1)* Charging of the capacitor**

The push-button switch is pushed to position (1).
Then capacitor undergoes charging.

a- The duration of the charging of the capacitor is very short .Why?

b- What would the value of the voltage $u_C = u_{AB}$ across the capacitor thus charged be?

***2)* Discharging of the capacitor**

The capacitor being charged, we release the push-button switch that returns automatically to position (2) at the instant $t_0 = 0$. The capacitor undergoes discharging through the resistor.

a- Determine, at an instant t , the differential equation that governs the variations of u_C as a function of time.

b- The solution of the previous differential equation has the form $u_C = a\ e^{\frac{-t}{\tau}}$ where a and τ are positive constants. Determine the expressions of a and τ in terms of E, R and C.

c- Show that, for $t = \tau$, the voltage across the capacitor is equal to 37 % of its value at the instant $t_0 = 0$.

B - Use of the apparatus

The lighting apparatus is represented by the circuit of figure 2 where E = 10V and the resistor is replaced by a lamp of resistance R = 3 kΩ.
The lamp illuminates as long as the voltage across its terminals is greater or equal to a limiting voltage denoted by U.

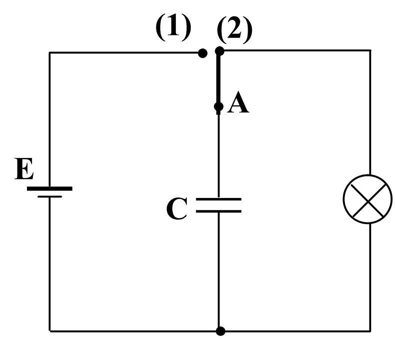

Figure 2

1) ***a-*** Using the solution of the differential equation [given in the question (A-2-b)], determine the expression of the duration t_1 of illumination of the lamp in terms of U, E and τ.

b- Calculate t_1 for U = 3.7 V and C = 2×10^{-2} F.

2) We keep the same lamp and the same DC source. Which component of the apparatus must be modified and how in order to increase the duration of illumination of the lamp?

<u>Third exercise</u> (6 ½ pts) Radioactivity of Cobalt

Cobalt $^{60}_{27}Co$ is a β^- radioactive. The daughter nucleus $^{A}_{Z}Ni$ undergoes a downward transition to the ground state. The energy due to this downward transition is E(γ) = 2.5060 MeV.

The β^- particle is emitted with a kinetic energy K.E (β^-) = 0.0010 MeV.

<u>**Numerical data:**</u> mass of the $^{60}_{27}Co$ nucleus: 59.91901 u ;
mass of the $^{A}_{Z}Ni$ nucleus : 59.91544 u ;
mass of an electron : 5.486×10^{-4} u ;
1 u = 931.5 MeV/c^2 ;
1 MeV = 1.6×10^{-13} J .

A –Study of the disintegration

1) Determine A and Z.
2) Calculate, in u, the mass defect Δm during this disintegration.
3) Deduce, in MeV, the energy E liberated by this disintegration.
4) During this disintegration, the daughter nucleus is practically obtained at rest. In what form of energy does E appear?
5) ***a-*** Deduce, from what preceded , that the electron, emitted by the considered disintegration, is accompanied by a certain particle.
b- Give the name of this particle.
c- Give the charge number and the mass number of this particle.
d- Deduce in MeV, the energy of this particle.
6) Write down the global equation of this disintegration.

B – The use of cobalt 60

In medicine, we use a source of radioactive cobalt $^{60}_{27}Co$ of activity A = 6×10^{19} Bq.

The emitted β^- particles are absorbed by the living organism.

1) The energy of the particle mentioned in the question (A-5) is not absorbed by the living organism. Why?
2) Calculate, in watt, the power transferred to the organism.
3) This large power is used in radiotherapy .What is its effect?

Solution

<u>First exercise</u> (7 pts)

1)

a- The distances covered during equal time intervals are equal. **(½ pt)**

b- $V_B = \frac{d}{t} = \frac{d}{4\tau} = \frac{0.2}{4\times 0.05} = 1 m/s.$ **(¾ pt)**

$V_A = \frac{0.24}{4\times 0.05} = 1.2 m/s.$ **(¾ pt)**

2) $\overrightarrow{P_{before}} = \vec{0}$; $\overrightarrow{P_{after}} = m_A \overrightarrow{V_A} + m_B \overrightarrow{V_B}$

$= 0.1(-1.2\vec{i}) + 0.12(\vec{i}) = \vec{0}$

$\Rightarrow \overrightarrow{P_{before}} = \overrightarrow{P_{after}}$;

The linear momentum is conserved for the system formed of the two pucks. **(1 pt)**

3)

a- Newton 2nd Law applied on A gives :

$\frac{d\vec{P}}{dt} = \overrightarrow{m_A g} + \overrightarrow{N_A} + \overrightarrow{F_{B\to A}} = \overrightarrow{F_{B\to A}}$

$= \frac{0.1(-1.2-0)\vec{i}}{0.05} = -2.4\vec{i}$. **(1 pt)**

$\frac{d\vec{P}}{dt} = \overrightarrow{m_B g} + \overrightarrow{N_B} + \overrightarrow{F_{A\to B}} = \overrightarrow{F_{A\to B}}$

$= \frac{0.12(1-0)\vec{i}}{0.05} = 2.4\vec{i}$. **(1 pt)**

b- $\overrightarrow{F_{B\to A}} = -\overrightarrow{F_{A\to B}}$ **(½ pt)**

4)

a- The deformed elastic shock ring. **(¼ pt)**

b- Elastic potential energy. **(¼ pt)**

c- The mechanical energy of the system is conserved because the system is isolated (The system does not exchange energy with the surroundings) ; (Elastic potential energy is transformed into kinetic energy):

$M.E = K.E + P.E_{el} = M.E_{before} = M.E_{after} = 0 + P.E_{el} = K.E + 0$

$\Rightarrow P.E_{el.} = \frac{1}{2}m_A V_A^2 + \frac{1}{2}m_B V_B^2 = 0.132 J$ **(1 pt)**

<u>Second exercise</u> (6 ½ pts)

A-

1) a- Because $\tau = RC \approx 0$ during charging. **(½ pt)**

b- $u_C = E$ **(¼ pt)**

2) a- $u_C = Ri$ and $i = -C\dfrac{du_C}{dt}$

$\Rightarrow u_C + RC\dfrac{du_C}{dt} = 0$ **(1 ¼ pt)**

b- $\dfrac{du_C}{dt} = -\dfrac{a}{\tau}e^{-\frac{t}{\tau}} \Rightarrow a\ e^{\frac{-t}{\tau}} + RC(-\dfrac{a}{\tau}e^{-\frac{t}{\tau}}) = 0$

$\Rightarrow 1 - \dfrac{RC}{\tau} = 0 \Rightarrow \tau = RC$;

For $t = 0$, $u_C = E = a$. **(1 ½ pt)**

c- If $t = \tau$, $u_C = Ee^{-1} = 0.37\ E = 37\%E$. **(1 pt)**

B-

1) a- $u_C = E\ e^{\frac{-t}{\tau}} \Rightarrow U = E\ e^{-\frac{t_1}{RC}}$

$\Rightarrow \dfrac{t_1}{RC} = \ln\dfrac{E}{U}$

$\Rightarrow t_1 = RC\ln\dfrac{E}{U} = \tau\ln\dfrac{E}{U}$. **(1 pt)**

b- $t_1 = 60$ s. **(½pt)**

2) Capacitor **(¼ pt)**

We must increase the value of C, Because t_1 is proportional to C. **(¼ pt)**

Third exercise (6 ½ pts)

A –

1) The conservation of charge number and of mass number gives :
$Z = 28$ and $A = 60$ **(½ pt)**

2) $\Delta m = m_{before} - m_{after}$
$= 59.91901 - (59.91544 + 0.0005486)$
$= 0.0030214$ u. **(½ pt)**

3) $\Delta m = 0.0030214 \times 931.5$ MeV/c^2
$= 2.8144$ MeV/c^2.
$E = \Delta m \times c^2 = 2.8144$ MeV **(¾ pt)**

4) E appears in the form of the kinetic energy of the obtained particles and of radiant energy of the γ photon.
(½ pt)

5) **a-** $K.E(\beta^-) + E(\gamma) = 0.0010 + 2.5060$
$= 2.507$ MeV

Is smaller than E = 2.8144 ; therefore there is no conservation of energy, thus there is a necessity to admit the emission of another particle other tan electron. **(1 pt)**

b- Antineutrino . **(¼ pt)**

c- $Z = 0$ and $A = 0$. **(½ pt)**

d- $E = 2.8144 - 2.507 = 0.3074$ MeV. **(½ pt)**

6) ${}^{60}_{27}Co \longrightarrow {}^{60}_{28}Ni + {}^{0}_{-1}e + {}^{0}_{0}\bar{\upsilon} + \gamma$ **(¼ pt)**

B –

1) Because the antineutrino does not interact with matter.
(¼ pt)

2) The activity corresponds to 6×10^{19} disintegrations per second, that means à 6×10^{19} electrons emitted per second
$\Rightarrow P = 6 \times 10^{19} \times 0.0010 \times 1.6 \times 10^{-13}$ W = 9.6 kW.
(1¼ pt)

3) The destruction of cells. **(¼ pt)**

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الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	

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

First exercise (7 points) Horizontal oscillator

Consider a mechanical oscillator that is formed of a spring (R) of stiffness k and a body (C), of mass m and of center of mass G.

A- Determination of k and m.

In order to determine the values of m and k of this oscillator, we place it on a horizontal air table. The table functioning normally, we shift (C) from its equilibrium position and we then release it from rest at the instant $t_0 = 0$. (C) may move then without friction on the table, G moving along a horizontal axis. The origin O of this axis is the position of G when (C) is at equilibrium.

x and v are respectively the abscissa and the algebraic measure of the velocity of G at the instant t.

Convenient equipments allow us to record the variations of x and v and on of the energies of the oscillator as a function of time. These variations are represented in the graphs of the figures1, 2 and 3. The horizontal plane containing G is taken as a gravitational potential energy reference Take: $\pi^2 = 10$.

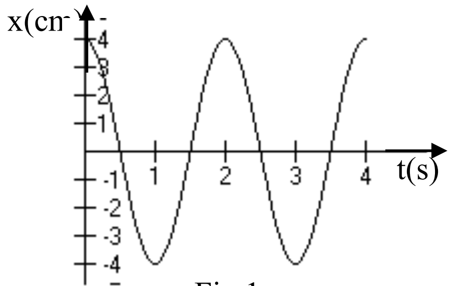


Fig.1

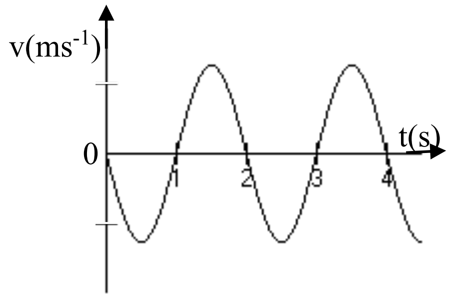


Fig.2

1) Referring to the graphs 1 and 2, determine:

a) The mode of the oscillations;

b) The initial values x_0 and v_0 of the motion;

c) The value of the proper period T_0 of the motion.

2) a) The figure 3 shows the variations of an energy E of the oscillator as a function of time. What form of energy is it? Justify.

b) The energy E is one of two terms of the mechanical energy M.E of the system (body, spring). Redraw figure 3 and show on it the shape of the variations of the mechanical energy M.E and that of the other form of that energy.

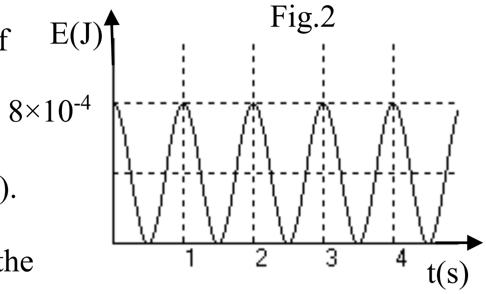


Fig.3

3) Deduce the values of m and k.

B- Driving the oscillations

The air table does not function normally any more and the forces of friction can no longer be neglected. We repeat the experiment under the same initial conditions. The variations of x, as a function of time, are recorded by an apparatus thus giving the graph of figure 4.

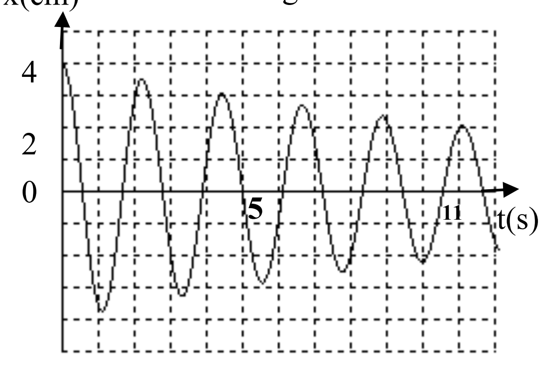


Fig.4

1

1) Specify the mode of oscillations performed by the oscillator.
2) Determine the value of the variation of the mechanical energy of the oscillator between the Instants: $t_0 = 0$ and $t = 11$ s.
3) A convenient apparatus allows us to drive these oscillations.
a) What does the term « driving » the oscillations represent?
b) Deduce the value of the average power of this apparatus between 0 and 11s.

Second exercise (7 points) Role of a capacitor in a circuit

The object of this exercise is to study the role of a capacitor in an electric circuit in two different cases.($g = 10 m/s^2$)

A- Variation of the current in a circuit

***1-* Qualitative study**

We connect the two circuits whose diagrams are represented in the diagram below; the two identical lamps L_1 and L_2 are fed respectively with two identical generators G_1 and G_2 each of constant voltage E , the component (D) being a capacitor that is initially uncharged (Fig.1).

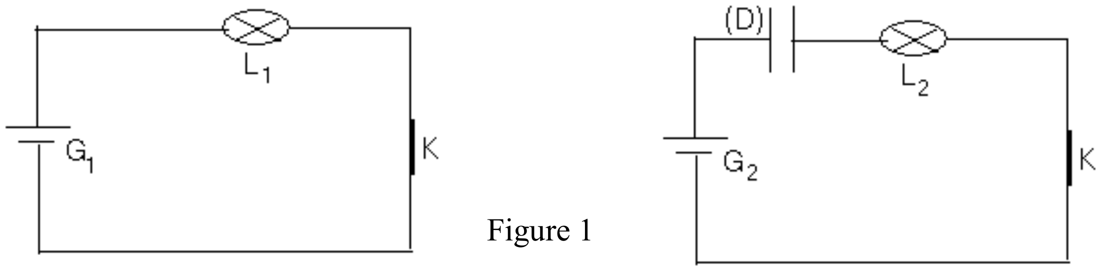


Figure 1

We close the two switches simultaneously at the instant $t_0 = 0$. We notice initially that L_1 and L_2 glow with the same brightness, but the brightness of the lamp L_2 decreases progressively and finally its light goes out, L_1 keeping its same brightness.

a) What can we say about the voltage across each of the lamps at the instant $t_0 = 0$? Justify.

b) i) How does the voltage across L_2 vary starting from the instant $t_0 = 0$?

ii) Deduce, when the light of L_2 goes out, the value of the voltage across the capacitor.

***2-* Quantitative study**

We connect a series circuit formed of a resistor of resistance R, a capacitor of capacitance C and a switch K across an ideal generator of e.m.f. E . At the instant $t_0 = 0$, the capacitor being uncharged, we close the switch K (Fig.2).

At the instant t, the charge of the armature B of the capacitor is q and the current carried by the circuit is i.

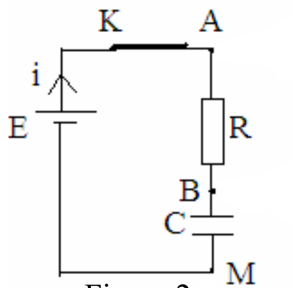


Figure 2

a. Write the relation between i and $\frac{dq}{dt}$.

b. Derive the differential equation in $u_{BM} = u_C$.

c. This differential equation has as solution: $u_C = E\,(1 - e^{-\frac{t}{\tau}})$

i) Determine the expression of τ in terms of R and C.

ii) Determine the expression of the current i in the circuit as a function of time.

iii) Draw the shape of each curve representing the variations of u_C and of i as a function of time.

3-Deduce the role of the capacitor in the variation of the current in an RC circuit fed by a DC voltage during the charging phase.

***B-* Energy stored in a capacitor**

1- Qualitative study

Consider the experiment whose diagram is represented in figure (3), where (M) is a motor to which an body of mass m is suspended, a capacitor of large capacitance, G an ideal generator of constant voltage E, and K_1 and K_2 are two switches.

In the first step of the experiment, we open K_2, and we close K_1.

In the second step of the experiment, we open K_1 and we close K_2. We observe that the body rises.

Explain what happens in each step of the experiment. a tell why the body rises

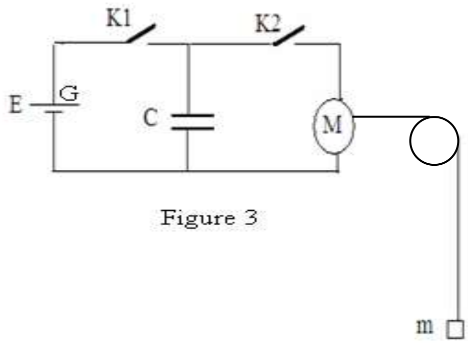


Figure 3

2- Quantitative study

The capacitor has a capacitance C = 1 F , the body has a mass m = 500g and the e.m.f of the generator is E = 3 V.

a- Calculate the energy initially stored in the capacitor.

b- Calculate the height rised by the body neglecting all energy losses.

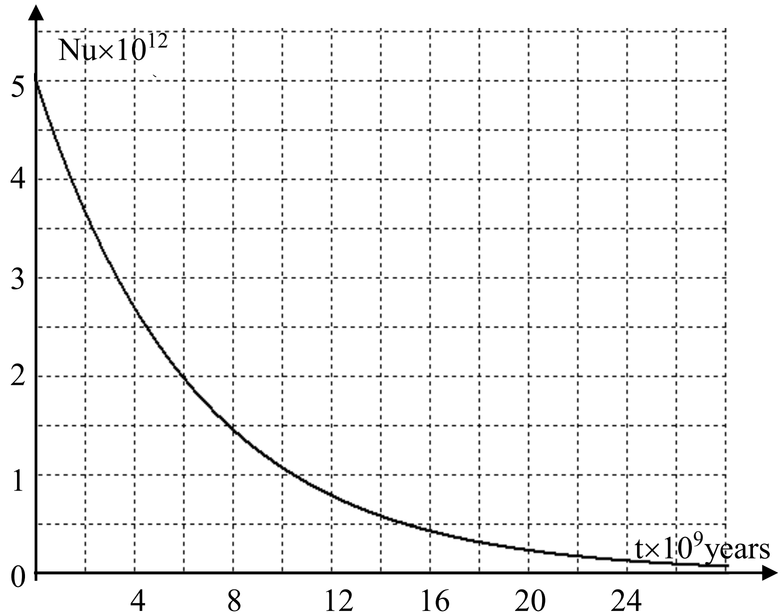
c- What type of energy transfer did take place?

d- In fact, the body rises 83 cm. Why?

e- Deduce the role of the capacitor in the previous circuit.

Third exercise (6 points) Determination of the age of the Earth

The object of this exercise is to determine the age of the Earth using the disintegration of a uranium 238 nucleus $\left({}^{238}_{92}U\right)$ into a lead 206 nucleus $\left({}^{206}_{82}\text{Pb}\right)$.



When we determine the number of lead 206 nuclei in a sample taken out from a rock that did not contain lead when it was formed, we can then determine its age that is the same as that of the Earth. The above figure represents the curve of the variation of the number N_u of uranium 238 nuclei as a function of time.

1 division on the axis of ordinates corresponds to 10^{12} nuclei.
1 division on the axis of abscissa corresponds to 10^{9} years.
The equation of the disintegration of Uranium 238 into lead 206 is:

$${}^{238}_{92}U \rightarrow {}^{206}_{82}Pb + x\beta^{-} + y\alpha$$

1 .Determine, specifying the laws used, the values of x and y.

2. Referring to the curve, indicate the number N_{0u} of uranium 238 nuclei existing in the sample at the date of its birth $t_o = 0$.

3. Referring to the curve , determine the period (half-life) of uranium 238.Deduce the value of the radioactive constant λ of uranium 238.

4. a) Give, in terms of N_{0u}, λ and t, the expression of the number N_u of uranium 238 nuclei remaining in the sample at instant t.

b) Calculate the number of uranium 238 nuclei remaining in the sample at instant $t_{1} = 2 \times 10^{9}$ years:

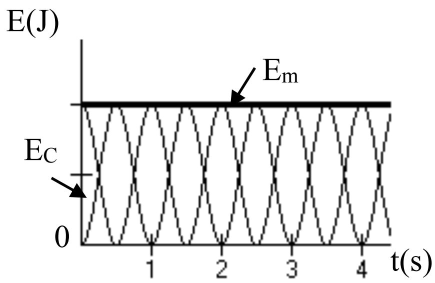
c) Verify this result graphically:

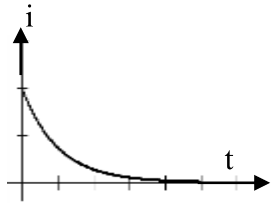
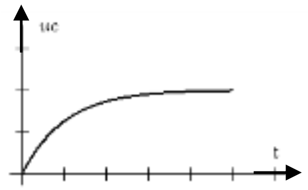
5. The number of lead 206 nuclei existing in the sample at the instant of measurement (age of the Earth) is $N_{pb} = 2.5 \times 10^{12}$ nuclei.

a) Give the relation among N_u, N_{0u} and N_{pb}.

b) Calculate the number N_u of uranium nuclei remaining in the sample at the date of measurement.

c) Determine the age of the Earth.

Part of the Q	Answer	Mark
	First exercise (7 points)	
A.1.a	Mode: free non-damped oscillations	0.50
A.1.b	At $t = 0$ we have: $x = x_0 = 4$ cm and $v = v_0 = 0$.	0.50
A.1.c	$T_0 = 2$ s	0.50
A.2.a	Elastic potential energy. Since at $t = 0$ $x = X_m$. And the value of that energy is maximum.	0.50
A.2.b	The curves are represented in the adjacent figure.  	1.25
A.3	$\frac{1}{2}kX_m^2 = 8\times10^{-4} \Rightarrow k = 1$ N/m. $T_0 = 2\pi\sqrt{\frac{m}{k}} \Rightarrow m = \frac{kT_0^2}{4\pi^2} \Rightarrow m = 0.1$ kg	1.50
B.1	Mode: Free and damped oscillations	0.50
B.2	$\Delta M.E = \frac{1}{2}kX_{m(t)}^2 - \frac{1}{2}kX_{m(0)}^2 = -6\times10^{-4}$ J.	0.75
B.3.a	Provides energy to compensate for the loss during the oscillations.	0.25
B.3.b	$P_{av} = \frac{\lvert\Delta M.E\rvert}{\Delta t} = 5.45\times10^{-5}$ W.	0.75
	Second exercise (7 points)	
A.1.a	the two voltages are equal because the lamps glow with the same brightness.	0.25
A.1.b.i	u_2 decreases, in fact $E = u_2 + u_C = cte$ but u_C increase thus u_2 decreases.	0.50
A.1.b.ii	- When the light of L_2 goes out $u_2=0 \Rightarrow E = u_C + u_2 = u_C \Rightarrow$ we can then find the voltage of the generator G_2 across the capacitor.	0.50
A.2.a	$i = \frac{dq}{dt}$	0.25
A.2.b	$E = Ri + u_C$, but $i = \frac{dq}{dt} = C\frac{du_C}{dt} \Rightarrow E = RC\frac{du_C}{dt} + u_C$.	0.75
A.2.c.i	$C\frac{du_C}{dt} = C\times\frac{E}{\tau}e^{-\frac{t}{\tau}} \Rightarrow E = R\times C\times\frac{E}{\tau}e^{-\frac{t}{\tau}} + E(1 - e^{-\frac{t}{\tau}})$ $\Rightarrow \frac{RC}{\tau} - 1 = 0 \Rightarrow \tau = RC$.	0.75

A.2.c.ii	$i = C\dfrac{du_C}{dt} = C \times \dfrac{E}{\tau}e^{-\frac{t}{\tau}} = \dfrac{E}{R}e^{-\frac{t}{\tau}}$.	0.50
A.2.c.iii	 	0.50
A.2.c.iv	The capacitor does not allow the passage of the current except during a short time when the circuit is fed by a DC voltage.	0.50
B.1	In the first step, the capacitor is charged till it reaches a voltage u_C= E. In the second step, the capacitor is discharged in the motor by providing across the motor a voltage u_C which decreases from the value E, thus it allows the lifting of the body.	0.50
B.2.a	W = 1/2 CE^2 = 1/2 (1)(9)= 4.5 J.	0.50
B.2.b	$W = mgh_{max} \Rightarrow h_{max} = \dfrac{4.5}{0.5\times10} = 0.9\,m$.	0.75
B.2.c	The electric energy stored in the capacitor is transformed into mechanical energy.	0.25
B.2.d	Because of friction	0.25
B.2.e	The capacitor stores electric energy and restitute this energy when needed.	0.25
	Third exercise (6 points)	
1	${}^{238}_{92}U \rightarrow {}^{206}_{82}Pb + x\,{}^{0}_{-1}e + y\,{}^{4}_{2}He$ The laws of conservation of the mass number and the charge number give $238 = 206 + 4y \Rightarrow y = 8$ α decays. $92 = 82 - x + 2y \Rightarrow x = 6$ β^- decays.	1.25
2	$N_{0ou} = 5 \times 10^{12}$ nuclei	0.50
3	For the half-life $N_u = \dfrac{N_{OU}}{2} = 2.5\times10^{12}$ nuclei. On the graph we find T $\approx 4.5\times10^9$ years. The radioactive constant $\lambda = \dfrac{0.693}{T} = \dfrac{0.693}{4.5\times10^9} = 1.54\times10^{-10}$ year $^{-1}$	1.50
4.a	$N_u = N_{ou}\,e^{-\lambda t}$	0.25
4.b	$N_u = 5 \times 10^{12}\ e^{-1.54\times10^{-10}\times2\times10^9} = 3.675 \times 10^{12}$ nuclei.	0.75
4.c	On the graph: 2×10^9 years corresponds 3.7×10^{12} nuclei	0.50
5.a	$N_{ou} = N_u + N_{Pb}$	0.25
5.b	a. $N_u = N_{ou} - N_{Pb} = 5 \times 10^{12} - 2.5 \times 10^{12} = 2.5 \times 10^{12}$ nuclei.	0.50
5.c	$N_u = \dfrac{N_{OU}}{2}$; the age of the Earth is equal to the half-life of uranium 238. this age is 4.5×10^9 years.	0.50

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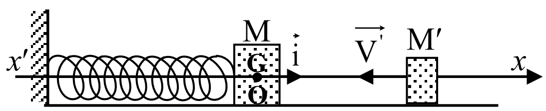
الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	

This exam is formed of three exercises in three pages.
The Use of non-programmable calculators is allowed.

<u>First exercise</u> (7 points)

Mechanical oscillator

A spring of un-jointed loops, of stiffness constant k = 10 N/m and of horizontal axis, is fixed from one extremity to a fixed obstacle; the other extremity is attached to a puck M of mass m = 100 g. The center of inertia G of M can slide, without friction, along a horizontal axis x'x of origin O and unit vector $\vec{i}$. The horizontal plane passing through G is taken as a gravitational potential energy reference.



At the instant $t_0 = 0$, the puck M, initially at rest at O, is hit with another puck M' of mass $m' = \frac{m}{2}$ moving initially with a velocity $\overrightarrow{V'} = -V'\vec{i}$ ($V' > 0$). After collision, the puck M' rebounds on M with a velocity $\overrightarrow{V'_1}$ and the puck M moves with a velocity $\overrightarrow{V_0} = V_0\vec{i}$, and performs oscillations with a constant amplitude $X_m = 10$ cm.

1) Give the sign of V_0.

2) Let x and v be respectively the algebraic values of the abscissa and the velocity of G at an instant t after the collision.

- **a)** Write, in terms of x, m, k and v, the expression of the mechanical energy of the system (M, spring, Earth) at the instant t.
- **b)** Derive the differential equation of second order in x that describes the motion of M.
- **c)** The solution of this differential equation is of the form $x = A\sin(\omega_0 t + \varphi)$. Determine the values of the positive constants A, ω_0 and φ.
- **d)** Deduce that the magnitude of the velocity $\overrightarrow{V_0}$ of M just after the collision is 1 m/s.

3) Knowing that the collision between M' and M is supposed to be perfectly elastic, determine:

- **a)** the value V' of the velocity of M' before collision;
- **b)** the velocity $\overrightarrow{V'_1}$ of M' just after the collision.

Second exercise (7 points)

Determination of the capacitance of a capacitor

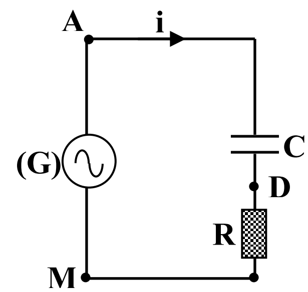


Figure 1

In order to determine the capacitance C of a capacitor, we connect it in series with a resistor of resistance $R = 10\sqrt{2}\ \Omega$ across the terminals of a low frequency generator (G) delivering across its terminals an alternating sinusoidal voltage $u_G = U_m \cos\omega t$.
The circuit thus constructed carries an alternating sinusoidal current i (Fig1).
Take $\sqrt{2} = 1.4$ and $0.32\pi = 1$.

1) Redraw the circuit of figure (1) and show the connections of the oscilloscope in order to display the voltages $u_G = u_{AM}$ across the generator and $u_R = u_{DM}$ across the resistor.
2) Which of the two voltages, u_G or u_R, represents the image of the current i ? Justify your answer.
3) In figure 2, the waveform (1) represents the variation of the voltage u_G with time.
   a) Specify, with justification, which of the voltages u_G or u_R, leads the other.
   b) Determine the phase difference between the voltages u_G and u_R.
4) Using the waveforms of figure 2, determine the angular frequency ω, the maximum value U_m of the voltage u_G and the maximum value I_m of the current i.
   Horizontal sensitivity: 5 ms/div.
   Vertical sensitivity on both channels: 1 V/div.
5) a) Write down the expression of the current i as a function of time t.
   b) Deduce the expression of the voltage $u_C = u_{AD}$ across the terminals of the capacitor as a function of C and t.
6) By applying the law of addition of voltages and giving the time t a particular value, determine the value of C.

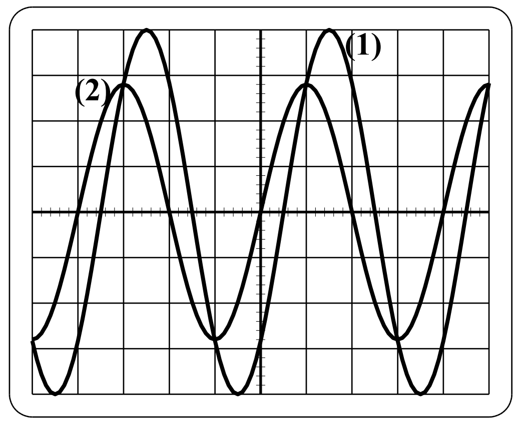
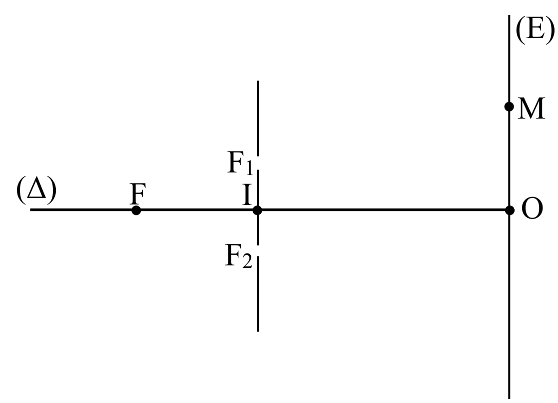


Figure 2

Third exercise (6 points)

Interference of light

Consider Young's experiment set-up that is formed of two very thin parallel slits F_1 and F_2, separated by a distance a = 1 mm , and a screen of observation (E) placed parallel to the plane of the slits at a distance D = 2 m from the mid point I of F_1F_2 and a thin slit F, equidistant from F_1 and F_2, situated on the straight line (Δ) whose intersection with (E) is the point O.
The object of this exercise is to study the interference pattern observed on the screen (E) in different situations.



A – First situation

The slit F is illuminated with a monochromatic light of wavelength $\lambda = 0.64\ \mu m$ in air.

1) Describe the interference pattern observed on (E).
2) Consider a point M on the screen at a distance d_1 from F_1 and d_2 from F_2.
   Specify the nature of the fringe thus formed at point M in each of the following cases:

a) $d_2 - d_1 = 0$;
b) $d_2 - d_1 = 1.28\ \mu m$;
c) $d_2 - d_1 = 0.96\ \mu m$.

3) F is moved along (Δ). We observe that the interference fringes remain in their positions. Explain why.
4) F is moved perpendicularly to (Δ) to the side of F_2. We observe that the central fringe is displaced. In which direction and why?

B – Second situation

Now the slit F is illuminated with white light.

1) We observe at point O a white fringe. Justify.
2) Specify the color of the bright fringe that is the nearest to the central fringe.

C – Third situation

Consider two lamps (L_1) and (L_2) emitting radiations of same wavelength, we illuminate F_1 by (L_1) and F_2 by (L_2), we observe that the system of interference fringes does not appear on the screen (E). Why?

<table>
<tr><td>الدورة الإستثنائية للعام 2008</td><td>امتحانات الشهادة الثانوية العامة
الفرع : علوم الحياة</td><td>وزارة التربية والتعليم العالي
المديرية العامة للتربية
دائرة الامتحانات</td></tr>
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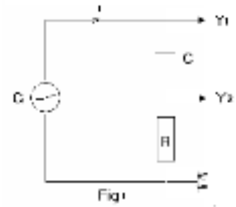
الرقم:</td><td>مسابقة في مادة الفيزياء
المدة ساعتان</td><td>مشروع معيار التصحيح</td></tr>
</table>

First exercise (7 points)

Part of the Q	Answer	Mark
1	$V_0 < 0$.	0.25
2.a	Mechanical energy: $ME = PE + KE = \frac{1}{2}k\cdot x^2 + \frac{1}{2}m\cdot V^2$	0.50
2.b	Without friction $\Leftrightarrow$ Conservation of mechanical energy $\Leftrightarrow ME = \frac{1}{2}k\cdot x^2 + \frac{1}{2}m\cdot V^2 = \text{constant}$. By deriving with respect to time: $\frac{dE_m}{dt} = kx\dot{x} + mV\dot{V} = 0$; $\Leftrightarrow \ddot{x} + \frac{k}{m}x = 0$.	1.00
2.c	$x = A\sin(\omega_0 t + \varphi)$; $\dot{x} = A\omega_0\cos(\omega_0 t + \varphi)$ and $\ddot{x} = -A\omega_0^2\sin(\omega_0 t + \varphi)$ By replacing in the differential equation: $A\omega_0^2\sin(\omega_0 t + \varphi) + \frac{k}{m}A\sin(\omega_0 t + \varphi) = 0 \Leftrightarrow \omega_0^2 = \frac{k}{m} = \frac{10}{0.1} = 100$, $\omega_0 = 10$ rd/s. For $t_0 = 0$, $x = A\sin(\varphi) = 0$, then $\varphi = 0$ or π and $v = A\omega_0\cos(\varphi) = V_0 < 0$; as $A > 0$, then $\cos\varphi < 0 \Rightarrow \varphi = \pi$ rad and $A = +10$ cm.	1.50
2.d	$v = \dot{x} = -\omega_0 A\cos(\omega_0 t)$; at $t_0 = 0$, $v = V_0 = -\omega_0 x_m = -1$ m/s.	0.75
3	Conservation of linear momentum: $\Leftrightarrow \vec{P}_i = \vec{P}_f \Leftrightarrow m'\vec{V}' = m'\vec{V}'_1 + m\vec{V}_0$ In algebraic values: $V' = V'_1 + 2V_0$. (I) Elastic collision $\Leftrightarrow$ Conservation of KE: $\Leftrightarrow \frac{1}{2}m'V'^2 = \frac{1}{2}m'V'^2_1 + \frac{1}{2}mV_0^2$ $\Leftrightarrow m'(V'^2 - V'^2_1) = mV_0^2$ (II) $\Leftrightarrow \frac{(II)}{(I)} \Leftrightarrow V' + V'_1 = V_0$ Substituting in(I) we obtain: $V' = \frac{3}{2}V_0 = 1.5\,V_0 = -1.5$ m/s.	2.00
4	$V'_1 = V_0 - V' = -1 - (-1,5) = 0.5$ m/s $\overrightarrow{V'_1} = 0.,5\ \vec{i}$	1.00

Second exercise (7 points)

Part of the Q	Answer	Mark
1		0.5
2	$u_R = Ri = ct\ i \Rightarrow u_R$ is the image of i.	0.50
3.a	u_R leads u_G , because in this circuit the current always leads the voltage across the generator.(u_R attains the maximum before).	0.5
3.b	$T \to 2\pi \to 4$ div. $\varphi \to 0.5$div=> $\varphi = \frac{\pi}{4}$ rad.	0.75
4	$T = 4\text{div} \times 5$ ms/div = 20 ms $\Rightarrow \omega = \frac{2\pi}{T} = \frac{2\pi}{0.02} = 100\pi$ rad/s. $U_m = 4$ div$\times$1 V/div = 4 V. $(U_R)_m = 2.8$ div$\times$1 V/div = 2.8 V = $2\sqrt{2}$ V = R I_m $\Rightarrow I_m = \frac{2\sqrt{2}}{10\sqrt{2}} = 0.2$ A.	2
5 a)	$i = I_m\cos(\omega t + \frac{\pi}{4}) = 0.2\cos(\omega t + \frac{\pi}{4})$	0.25
5 b)	$i = \frac{dq}{dt} = C\frac{du_C}{dt} \Rightarrow u_C = \frac{1}{C}$ primitive of $i = \frac{0.2}{100\pi C}\sin(\omega t + \frac{\pi}{4})$	1
6	$u_G = u_C + u_R$; $u_R = 2\sqrt{2}\cos(\omega t + \frac{\pi}{4})$ $4\cos\omega t = \frac{0.2}{100\pi C}\sin(\omega t + \frac{\pi}{4}) + 2\sqrt{2}\cos(\omega t + \frac{\pi}{4})$. For t = 0, we have : $4 = \frac{0.2}{100\pi C} \times \frac{\sqrt{2}}{2} + 2\sqrt{2}\frac{\sqrt{2}}{2} \Rightarrow$ $C = 224 \times 10^{-6}$F = 224 μF.	1.50

Third exercise (6 points)

Part of the Q	Answer	Mark
A.1	- Fringes are parallel to the slits - Fringes are alternately bright and dark - Fringes are equidistant	0.75
A.2.a	d_2-d_1 = 0 = kλ with k = 0 ; M is a bright central fringe.	0. 5
A.2.b	d_2-d_1 = 1.28 µm = kλ with k = 2 ;M is a bright fringe of order 2.	0.75
A.2.c	d_2-d_1 = 0.96 µm = $(2k + 1)\lambda / 2$ with k = 1 ; M is a dark fringe of order 1	0.75
A.3	FF_1 remains equal to FF_2, the optical path difference $\delta = \frac{ax}{D}$ does not vary thus the interfringe i does not vary.	0.75
A.4	$FF_1 > FF_2$; the optical path FF_1M increases. To locate the central bright fringe O', we must have $FF_1O' = FF_2O'$, the optical path F_2O' must increase $\Rightarrow$the central fringe is displaced to the side of F_1.	1
B.1	We see at O a white fringe since all the bright fringes corresponding to different colors superpose at O.	0.5
B.2	$x = k\frac{\lambda D}{a}$ **;** for k =1 **,** x is the smallest value corresponding to the smallest wavelength $\Rightarrow$ we observe a violet bright fringe.	0.75
C	No, since the two sources are not coherent.	0.25

6

دورة سنة ٢٠٠٨ العادية الإكمالية	امتحانات الشهادة الثانوية العامة فرع علوم الحياة	وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات
الاسم: الرقم:	مسابقة في مادة الفيزياء المدة: ساعتان	

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

First exercise (7 points) Harmonic oscillator

In order to study a harmonic oscillator, we consider a solid (S) taken as a particle of mass m = 100g and two identical springs (R_1) and (R_2) of un-jointed turns each of stiffness k and of free length L_0. The oscillator thus formed is represented in figure 1.
At equilibrium, (S) is at the origin O of the axis x'x on which $\vec{i}$ is a unit vector and the length of each spring is L_0.

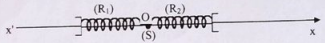


Fig 1

(S) is shifted from this position by a distance d to the right and then released without velocity at the instant $t_0 = 0$. At an instant t, the abscissa of (S) is x, the algebraic value of its velocity is v = x' and that of its acceleration is x''.
(S) would thus oscillate, without friction, on the axis x'x ; the horizontal plane containing this axis is taken as a gravitational potential energy reference.

A- Differential equation

1) Write, at the instant t , the expression of the mechanical energy of the system [(S), springs]
2) Derive the differential equation that governs the motion of (S).
3) Deduce the expression of the proper angular frequency ω_0 of the motion in terms of k and m.

B- Values of some physical quantities

A convenient apparatus is used to trace the curve of the variations of the acceleration as a function of the abscissa: x" = f(x) (figure 2).

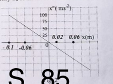


Fig 2

1) Show that the curve representing the acceleration x" = f(x) agrees the differential equation just derived.
2) Referring to the graph :
a) Give the value of the amplitude X_m of the motion;
b) Give the value of the acceleration x" for x = $-X_m$;
c) Find the value of the proper angular frequency ω_0 of the motion.
3) a) Show that the speed of (S) is maximum when it passes through its equilibrium position.
b) Deduce the value V_{max} of the maximum speed.
4) Calculate the value of the spring constant k.

Second exercise (7 points) RLC series circuit

The object of this exercise is to determine the approximate values of the characteristics of a capacitor and a coil.

We consider then the electric circuit represented by figure 1. This circuit contains, in series, a capacitor of capacitance C, a coil of inductance L and of resistance r and a resistor of resistance $R = 20\ \Omega$.

The setup thus formed is connected across a generator delivering an alternating sinusoidal voltage u of adjustable frequency f.

An alternating sinusoidal current i passes then in the circuit.

An oscilloscope conveniently branched allows us to display the voltage $u = u_{AM}$ across the terminals of the generator on channel Y_1 and the voltage u_{BM} across the terminals of the resistor on channel Y_2.

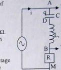


Fig. 1

The adjustments of the oscilloscope are as follows:

Horizontal sensitivity(time base): : $S_h = 2$ms/div

Vertical sensitivity :

- On channel Y_1 : S_{V1}= 2V/div
- On channel Y_2 : S_{V2}= 0.25V/div

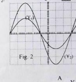


Fig. 2

1. We vary the value f of the frequency. For a value f_o of f, we observe on the screen of the oscilloscope the waveforms represented by figure 2.

a) The waveforms show that the circuit is the seat of a physical phenomenon .Name this phenomenon and give, in this case, the relation among f_o , L and C.

b) Determine the value of f_o.

c) Determine U_m the maximum value of u and I_m that of i.

d) The circuit is equivalent to a resistor of resistance $R_t = R + r$. Determine R_t and r .

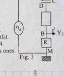


Fig. 3

2. The coil is replaced by a resistor of resistance $r' = 60\ \Omega$ (Fig. 3). The voltage across the terminals of the generator is $u = U_m \cos 2\pi f_0 t$. On the screen, we observe the waveforms represented in figure 4. The adjustments of the oscilloscope are the same as the previous ones.

a) The voltage u_{AM} lags u_{BM}. Why?

b) Calculate the phase difference φ between u_{AM} and u_{BM}.

c) Determine the instantaneous expression of u_{BM} .

d) Calculate the maximum value I_m of the current i and determine its instantaneous expression.

e) Verify that the expression of the voltage across the terminals of the capacitor is given by:

$$u_{AD} = \frac{8.9\times10^{-5}}{C}\sin\left(125\pi t + \frac{\pi}{4}\right). \quad (u_{AD} \text{ in V; t in s})$$

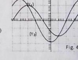


Fig. 4

f) Applying the law of addition of voltages and giving t a particular value, calculate the value of C.

g) Using the relation found in (*1,a*) , calculate L.

Third exercise (6 points) The Orion Nebula

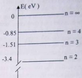


Fig. 1

The great Orion Nebula is composed of four very hot stars emitting ultraviolet radiation whose wavelength in vacuum is less than 91.2 nm, within a large «cloud» of interstellar gas formed mainly of hydrogen atoms.
The diagram of figure 1 represents some of the energy levels E_n of the hydrogen atom.

Given: Planck's constant: $h = 6.626\times10^{-34}$ J.s;
speed of light in vacuum: $c = 2.998\times10^{8}$ ms^{-1};
1 eV $= 1.602\times10^{-19}$ J;
spectrum of rosy color: 640 nm $\leq \lambda \leq$ 680 nm;
visible spectrum: 400 nm $\leq \lambda \leq$ 800 nm.

A- ***1)*** By convention, the energy of the hydrogen atom in the ionized state is considered zero. Use this convention to justify the (-) sign of E_n.

2) The hydrogen atom is in its fundamental [ground] state.

a) Show that the minimum value of the energy needed to ionize this atom is equal to: $E_i = 2.178\times10^{-18}$ J.

b) Calculate the wavelength λ_i of the wave associated to the photon whose energy is equal to E_i.

c) Show that the light, emitted by the very hot stars in the Orion Nebula, can ionize the hydrogen atoms of the interstellar gas.

Specify the dynamic state of these extracted electrons.

B- The interstellar gas in the Orion Nebula being ionized, some extracted electrons are captured by protons at rest (ionized hydrogen atoms) to form hydrogen atoms in an excited state. An excited hydrogen atom undergoes then a progressive downward transition.

1) Color of the Orion Nebula

Out of the possible transitions, we consider the transition of the atom from level 3 to level 2.

a) Calculate the wavelength, in vacuum, of the radiation corresponding to this transition.

b) This radiation is visible. Why?

c) Justify then the rosy color of the Nebula.

2) Maximum temperature on the surface of the Orion nebula

The electron before it is captured by the hydrogen ion H^+ has a kinetic energy KE. The total energy of the system (ion + electron) $E = 0 + KE$ is conserved.
When the atom undergoes a downward transition, after capturing the electron, it passes to an excited state characterized by its energy level E_n, by emitting a photon of frequency ν so that: $K.E = E_n + h\nu$.

a) Show that for n = 2, we have: $\nu = \dfrac{KE}{h} + 8.22\times10^{14}$ (ν in Hz)

b) The average kinetic energy of the electrons is related to the temperature on the surface of the star by : $K.E = \dfrac{3}{2}kT$. ($k = 1.38\times10^{-23}$ SI); and T is the temperature in Kelvin.

We notice that the smallest wavelength, in the emission band of rays of the Orion Nebula, is $\lambda = 245$ nm in vacuum.

i) Show that this ray corresponds to (K.E) [illegible]. Calculate (K.E) [illegible].

ii) Deduce the maximum value of T.

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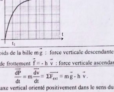
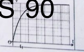
مشروع معيار التصحيح	مسابقة في مادة الفيزياء المدة: ثلاث ساعات	الاسم: الرقم:

Partie de la Q.	Corrigé	Note
	Premier exercice (7 points)	0.5
A.1	$E_m = 1/2\ mv^2 + kx^2$	
A.2	$\frac{dE_m}{dt} = mx'x'' + 2kxx' = 0 \Rightarrow x'' + \frac{2k}{m}x = 0.$	0. 5
A.3	Cette équation est de la forme : $x'' + \omega_0^2 x = 0 \quad \omega_0 = \sqrt{\frac{2k}{m}}$.	0,75
B.1	$x'' = -\omega_0^2 x$ est bien une droite de coefficient directeur $-\omega_0^2$	0,5
B.2.a	$X_m = 10$ cm.	0.25
B.2.b	$x'' = 100\ m/s^2$	0.75
B.2.c	L'équation différentielle s'écrit : $x'' + \omega_0^2 x = 0 \Rightarrow x'' = -\ \omega_0^2 x$; le coefficient directeur de la droite est : $\frac{100}{-0{,}1} = -1000\ s^{-2} \Rightarrow \omega_0 = \sqrt{1000} = 31{,}6\ rad/s$	1
B.3a	En passant par la position d'équilibre x = 0 ; le graphique montre que pour x = 0, x'' = 0 $\Rightarrow \frac{dV}{dt} = 0 \Rightarrow$ V est maximale.	0.75
B.3.b	Conservation de l'E_m $\Rightarrow \frac{1}{2}mV_{max}^2 = kX_m^2 \Rightarrow \lvert V_{max}\rvert = \omega_0 X_m \Rightarrow V_{max} = 3{,}16\ \ m/s.$	0,75
B.4	$\omega_0^2 = \frac{2k}{m} \Rightarrow k = 50\ \ N/m.$	1,25
	Deuxième exercice (7 points)	
1.a	Résonance d'intensité , car la tension aux bornes du générateur et celle aux bornes du conducteur ohmique (image du courant) sont en phase. $f_o = \frac{1}{2\pi\sqrt{LC}}$	0.75
1.b	$T_o = 8 \times 2 = 16$ ms $\Rightarrow f_o = \frac{1}{T_o} = \frac{1}{16x10^{-3}} = 62{,}5 Hz$ et $\omega_o = 2\pi f_o = 125\ \pi$ rd/s	0.50
1.c	$U_m = 2 \times 2 = 4$ V $U_{Rm} = 4 \times 0{,}25 = 1\ V \Rightarrow I_m = \frac{U_{Rm}}{R} = \frac{1}{20} = 0{,}05$ A	0,75
1.d	Car u et i sont en phase . $U_m = R_t\,I_m \Rightarrow R_t = \frac{4}{0{,}05} = 80\ \Omega$ $r = R_t - R = 60\Omega$	1
2.a	u_{BM} (image de i) est en avance de phase sur u_{g} ... Ceci est prévu car le circuit est capacitif .	0.25
2.b	2π rd $\rightarrow$ 8 div $\varphi \rightarrow$ 1div $\Rightarrow \varphi = \frac{2\pi}{8} = \frac{\pi}{4} rd$	0.25
2.c	$U_{BMmax} = 2{,}8x0{,}25 = 0{,}7$ V ; $\omega_o = 125\ \pi$ rd	0.75

	$\Rightarrow u_{BM} = 0,7\cos(125\pi t + \pi/4)$ (u_{BM} en V, t en s) $U_m = 2x2 = 4$ V alors $u = 4\cos 125\pi t$ (u en V, t en s)	
2.d	$I_m = \frac{U_{BM\,max}}{R} = \frac{2,8x0,25}{20} = 0,035$ A $\Rightarrow i = 0,035\cos(125\pi t + \frac{\pi}{4})$ (i en A, t en s)	0.50
2.e	$i = \frac{dq}{dt}$ et $q = C\,u_c \Rightarrow i = C\frac{du_c}{dt} \Rightarrow C\frac{du_c}{dt} = I_m\cos(125\pi t + \frac{\pi}{4})$ $\Rightarrow u_c = \frac{I_m}{C}\int\cos(125t + \frac{\pi}{4})dt = \frac{I_m}{125\pi C}\sin(125\pi t + \frac{\pi}{4})$ $u_c = \frac{8,9x10^{-5}}{C}\sin(125\pi t + \frac{\pi}{4})$	0.75
2.f	Additivité des tensions : $u_{AM} = u_{AD} + u_{DB} + u_{BM}$ $\Rightarrow 4\cos 125\pi t = \frac{8,9x10^{-5}}{C}\sin(125\pi t + \frac{\pi}{4}) + 80\times0,035\cos(125\pi t + \frac{\pi}{4})$ Pour $125\pi t = \frac{\pi}{2}$ on a : $0 = \frac{8,9x10^{-5}}{C}\sin(\frac{\pi}{2} + \frac{\pi}{4}) + 2,8\cos(\frac{\pi}{2} + \frac{\pi}{4}) \Rightarrow$ $-\frac{8,9\times10^{-5}}{C}\times\frac{\sqrt{2}}{2} = 2,8(-\frac{\sqrt{2}}{2}) \Rightarrow C = 32\times10^{-6}\,F = 32\,\mu F$	1.00
2.g	$LC = 6,49 \times 10^{-6} \Rightarrow L = \frac{6,49\times10^{-6}}{32\times10^{-6}} = 0,2$ H	0.50
	Troisième exercice (6 points)	
A.1	Pour ioniser un atome d'hydrogène, pris dans un état d'énergie E_n, il faut lui fournir une énergie W telle que: $W + E_n = 0$. Or W est sûrement > 0, donc **$E_n < 0$.**	0.50
A.2.a	Puisqu'il s'agit de l'énergie minimale donc l'électron arraché est au repos; alors : $E_i = E_\infty - E_1 = E_i = 13,6$ eV $= 13,6\times1,602\times10^{-19} = 2,178\times10^{-18}$ J.	0.75
A.2.b	$\lambda_i = \frac{hc}{E_i} = \frac{6,626\times10^{-34}\times2,999\times10^{8}}{2,178\times10^{-18}}$ **$= 91,24\times10^{-9}$ m = 91,24 nm**	0.75
A.2.c	Comme λ de la lumière rayonnée par les étoiles chaudes est $< \lambda_i$ $\Rightarrow E > E_i$ alors les atomes d'hydrogène du gaz interstellaire sont ionisés et les électrons arrachés possèdent de l'E_C.	0.75
B.1.a	$\lambda_{32} = \frac{hc}{E_3 - E_2}$ **$= 656,3\times10^{-9}$ m = 656,3 nm.**	0.75
B.1.b	Oui elle est visible car 400 nm $\leq \lambda_{32} \leq$ 800 nm.	0.25
B.1.c	Parce que 640 nm $\leq \lambda_{32} \leq$ 680 nm	0.25
B.2.a	$E_C = E_2 + h\nu \Rightarrow \nu = \frac{E_C}{h} - \frac{E_2}{h} = \frac{E_C}{h} + \frac{3,4\times1,602\times10^{-19}}{6,626\times10^{-34}}$. $\nu = \frac{E_C}{h} + 8,22\times10^{14}$ Hz	0.75
B.2.b.i	Comme il s'agit de $\lambda_{min} \Rightarrow \nu_{max} \Rightarrow (E_C)_{max}$. $\frac{c}{\lambda_{min}} = \frac{(E_C)_{max}}{h} + 8,22\times10^{14} \Rightarrow (E_C)_{max} = 2,66\times10^{-1[illegible]}$ J.	0.75
B.2.b.ii	$E_C = \frac{3}{2}kT \Rightarrow T_{max} = 12850$ K.	0.50
	Quatrième exercice (7.5 points)	

A.1	$E = u_R + u_L$. $E = Ri + L\frac{di}{dt}$ (1).	0.50
A.2	$\frac{di}{dt} = \frac{E}{R} \times (\frac{R}{L}) e^{-\frac{R}{L}t} = \frac{E}{L} e^{-\frac{R}{L}t}$, en remplaçant dans l'équation différentielle on obtient : $E = R\frac{E}{R}(1 - e^{-\frac{R}{L}t}) + L(\frac{E}{L} e^{-\frac{R}{L}t}) = E$.	0.75
A.3	Si $t \to \infty$, $e^{-\frac{R}{L}t} \to 0 \Rightarrow i = \frac{E}{R} = I_{max}$.	0.50
A.4	$i = \frac{E}{R}(1 - e^{-\frac{R}{L}t_1}) = 0,63 I_{max} = 0,63\frac{E}{R} \Rightarrow 1 - e^{-\frac{R}{L}t_1} = 0,63 \Rightarrow e^{-\frac{R}{L}t_1} = 1 - 0,63 = 0,37$ $\Rightarrow -\frac{R}{L}t_1 = \ln 0,37 = -0,99 \approx -1 \Rightarrow t_1 = \frac{L}{R}$.	0.75
A.5	Graphe 	0.75
B.1	Le poids de la bille $m\vec{g}$: force verticale descendante La force de frottement $\vec{f} = -h\,\vec{v}$: force verticale ascendante.	0.25
B.2	$\frac{d\vec{P}}{dt} = m\frac{d\vec{v}}{dt} = \Sigma\vec{F}_{ext} = m\vec{g} - h\,\vec{v}$. Par projection sur un axe vertical orienté positivement dans le sens du mouvement on obtient : $m\frac{dv}{dt} = mg - hv \Rightarrow mg = hv + m\frac{dv}{dt}$ (2).	1
C.1	E correspond à mg ; R correspond à h ; i correspond à v ; L correspond à m ; $\frac{di}{dt}$ correspond à l'accélération $\frac{dv}{dt}$.	1.25
C.2.a	Par analogie, on peut déduire que : $v = \frac{mg}{h}(1 - e^{-\frac{h}{m}t})$	0.50
C.2.b	Si $t \to \infty$, $e^{-\frac{h}{m}t} \to 0 \Rightarrow v = \frac{mg}{h} = v_{limite}$.	0.50
C.2.c	$v = 0,63 v_{limite} = 0,63\frac{mg}{h} = \frac{mg}{h}(1 - e^{-\frac{h}{m}t_1}) \Rightarrow$ $0,63 = 1 - e^{-\frac{h}{m}t_1} \Rightarrow e^{-\frac{h}{m}t_1} = 0,37 \Rightarrow -\frac{h}{m}t_1 = \ln 0,37 = -0,99 \approx -1 \Rightarrow t_1 = \frac{m}{h}$.	0.50
C.3	Graphe 	0.25

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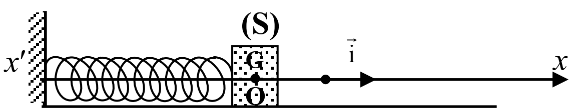
الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	

This exam is formed of three exercises in three pages numbered from 1 to 3
The use of non-programmable calculators is recommended.

<u>First Exercise</u> (7 points)

Horizontal elastic pendulum

The free end of a spring of horizontal axis $(O, \vec{i})$, of negligible mass and of stiffness k = 15 N/m, is connected to a solid (S) of mass m. (S) is free to move on a horizontal table and G, center of mass of (S), may move along the horizontal axis $(O, \vec{i})$.



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

_A_ – Theoretical study

G , shifted from its equilibrium position O by a distance x_0 in the positive direction along the axis $(O, \vec{i})$, is released from rest at the instant $t_0 = 0$. (S) thus performs simple harmonic oscillations of proper period T_0.

At an instant t, the abscissa of G is x and the algebraic value of its velocity is $v = \frac{dx}{dt}$.

1) Give the expression of the mechanical energy of the system [(S),spring, Earth] at the instant t in terms of k, m, x and v .

2) Derive the second order differential equation in x that governs the motion of G.

3) ***a)*** The solution of this equation has the form: $x = X_m \cos\left(\frac{2\pi}{T_0}t + \varphi\right)$. Determine, in terms of the given constants, the expressions of T_0 and X_m and calculate the value of φ.

b) Write down the instantaneous expression of v. Deduce the relation between x_0 , T_0 and the maximum value V_m of v.

_B_ – Experimental study

I – We record, as a function of time, the variations of the abscissa x of G (figure 1) and that of v (figure 2).

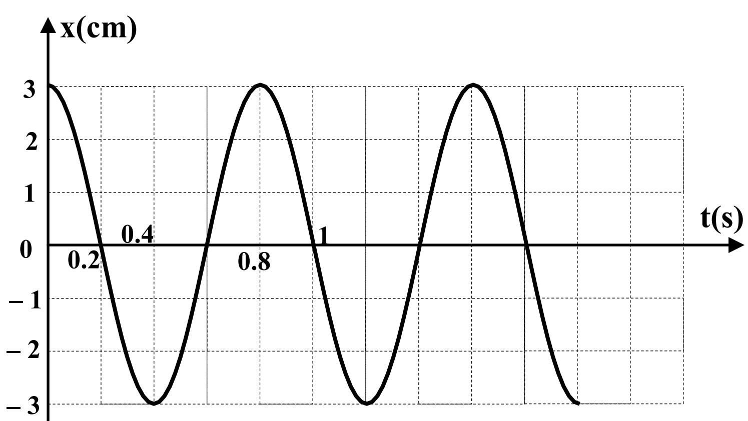


Fig. 1

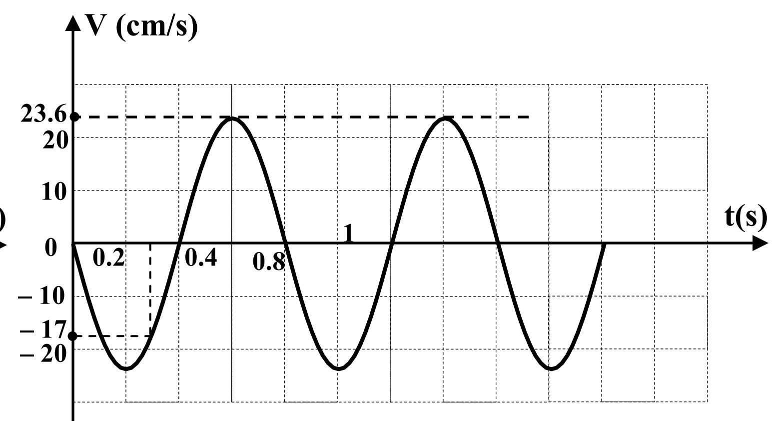


Fig. 2

1

1) Referring to the graphs of figures 1 and 2, specify the value of T_0, that of V_m and the values of x and v at the instant $t_0 = 0$.

2) Determine the mass m of (S).

II – 1) Copy and complete the table below , where K.E is the kinetic energy of (S) , $P.E_e$ is the elastic potential energy of the spring and M.E is the mechanical energy of the system [(S), spring, Earth]

t(s)	0	0.2	0.3
v(m/s)		– 0.236	– 0.17
K.E (J)		6.77×10^{-3}	
x(m)	0.030		– 0.021
$P.E_e$ (J)	6.75×10^{-3}		
M.E (J)			

2) Deduce from the table an indicator that confirms that the oscillations are simple harmonic.

<u>Second Exercise</u> (7 points)

Measurement of the speed of a plane

The aim of this exercise is to measure the speed of a plane using the phenomenon of electromagnetic induction.

A **– Motion of a conductor in a uniform magnetic field**

A homogeneous metallic rod MN of length ℓ, slides on two horizontal and parallel metallic rails AA' and EE' at a constant velocity $\vec{v}$. During its sliding, the rod remains perpendicular to the rails and its center of mass G moves along the axis Ox.

At the instant $t_0 = 0$, G is at O, the origin of abscissa. At an instant t, the abscissa of G is $x = \overline{OG}$ and $v = \frac{dx}{dt}$ is the algebraic value of its velocity. The whole set-up formed of the rod and the rails is put within a uniform magnetic field $\vec{B}$ perpendicular to the plane of the horizontal rails (Figure 1).

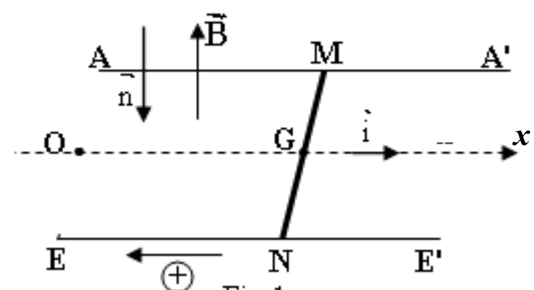


Fig. 1

1) Determine, at the instant t, the expression of the magnetic flux crossing the surface AMNE in terms of B, ℓ and x, taking into consideration the chosen arbitrary positive direction on figure 1.

2) Explain the existence of an induced e.m.f e across the ends M and N of the rod.

3) Determine the expression of the induced e.m.f e in terms of B, ℓ and v.

4) No current would pass in the rod. Why?

5) Deduce the polarity of the points M and N of the rod and give the expression of the voltage u_{NM} in terms of e.

.

B – Measurement of the speed of a plane

A plane is flying horizontally along a straight path with a constant velocity $\vec{v_1}$ of magnitude v_1 within the uniform magnetic field $\vec{B}$ of the Earth. The vector $\vec{B}$, in the region of flight, has a horizontal component of magnitude $B_h = 2.3\times10^{-5}$ T and a vertical component of magnitude $B_v = 4\times10^{-5}$ T.

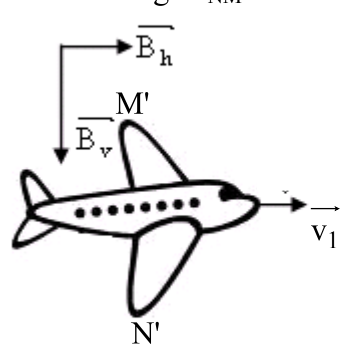


Fig.2

The wings of the plane, considered as a straight and horizontal conductor of length ℓ' = M'N' = 30 m, sweep with time a surface area (Figure 2).

1) ***a)*** The magnetic flux of $\overrightarrow{B_h}$ through the swept surface area is zero. Why?

b) Give the expression of the induced e.m.f e_1 that appears between the ends M' and N' of the wings in terms of B_v, ℓ' and v_1.

2) Determine v_1, if the potential difference across the wings has a value 0.36 V.

<u>Third Exercise</u> (6 points)

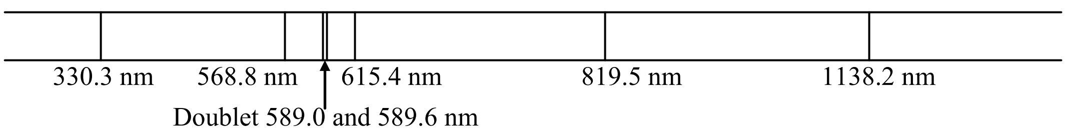
Sodium vapor lamp

Sodium vapor lamps are used to illuminate roads. These lamps contain sodium vapor under very low pressure. This vapor is excited by a beam of electrons that cross the tube containing the vapor. The electrons yield energy to the sodium atoms which give back this received energy during their downward transition towards the ground state in the form of electromagnetic radiations.

<u>Given</u>: $h = 6.62\times10^{-34}$ J.s; $c = 3\times10^{8}$ ms^{-1}; $e = 1.60\times10^{-19}$ C ; 1 nm = 10^{-9}m.

1) What do each of the quantities h, c and e represent?

2) The analysis of the emission spectrum of a sodium vapor lamp shows the presence of lines of well-determined wavelengths λ. The figure below represents some of the lines of this spectrum.



a) The yellow doublet of wavelengths, in vacuum, λ_1= 589.0 nm and λ_2 = 589.6 nm is more intense than the other lines.

i) To what range: visible, infrared or ultraviolet, does each of the other lines of the spectrum belong?

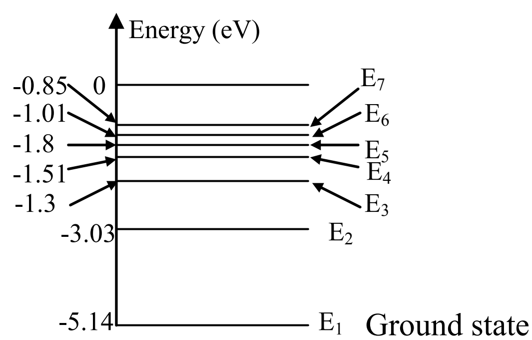
ii) The sodium vapor lamps are characterized by the emission of yellow light. Why?

b) Is the visible light emitted by the sodium lamp monochromatic or polychromatic? Justify your answer.

3) ***a)*** Referring to the diagram of the energy levels of the sodium atom in the adjacent figure:

i) Specify an indicator that justifies the discontinuity of the emission spectrum of the sodium vapor lamp.

ii) Verify that the emission of the line of wavelength λ_1 corresponds to the downward transition from the energy level E_2 to the ground state.



b) In fact, the energy level E_2 is double, i.e., it is constituted of two energy levels that are very close to each other. Draw a diagram that shows the preceding downward transition as well as the downward transition corresponding to the emission of the radiation of wavelength λ_2.

4) The sodium atom, being in the ground state, is hit successively by the electrons (a) and (b) of respective kinetic energies 1.01 eV and 3.03 eV .

a) Determine the electron that can interact with the sodium atom.

b) Specify the state of the sodium atom after each impact.

c) Deduce, after impact, the kinetic energy of the electron that interacts with the sodium atom.

First Exercise (7 points)

A –

1) Expression of the mechanical energy: $ME = \frac{1}{2} mv^2 + \frac{1}{2} kx^2$ **(¼)**

2) There is a conservation of the mechanical energy: ME = constant, then $\frac{dE_m}{dt} = 0$

$\frac{1}{2} m\, 2\, vV' + \frac{1}{2} k 2xx' = 0$. $m\dot{x}(\ddot{x} + \frac{k}{m}x) = 0$; as $\dot{x} \neq 0$ $\forall$ t, then: $\ddot{x} + \frac{k}{m}x = 0$ **(¾)**

3) **a)** $x = X_m \cos(\frac{2\pi}{T_0}t + \varphi)$; $\frac{dx}{dt} = \dot{x} = -\frac{2\pi}{T_0} X_m \sin(\frac{2\pi}{T_0}t + \varphi)$;

$\frac{d^2x}{dt^2} = \ddot{x} = -X_m \left(\frac{2\pi}{T_0}\right)^2 \cos(\frac{2\pi}{T_0}t + \varphi)$ By replacing in the differential equation and by we obtain:

$\ddot{x} + \left(\frac{2\pi}{T_0}\right)^2 x = 0$, while comparing : $\left(\frac{2\pi}{T_0}\right)^2 = \frac{k}{m}$

$\Rightarrow T_0 = 2\pi\sqrt{\frac{m}{k}}$

For $t_0 = 0$, $X_m \cos(\varphi) = x_0 > 0$ and $v = -\frac{2\pi}{T_0} X_m \Rightarrow \sin(\varphi) = 0$

$\Rightarrow \varphi = 0$ or π. But $X_m > 0 \Rightarrow \cos\varphi = 1$ thus $X_m = x_0$ and $\varphi = 0$ **(1¾)**

b) $v = \frac{dx}{dt} = \dot{x} = -\frac{2\pi}{T_0} x_0 \sin(\frac{2\pi}{T_0}t)$; $\Rightarrow |V_m| = \frac{2\pi}{T_0} x_0$ **(1)**

B – I – **1)** $T_0 = 0.8$ s, $x_0 = 3$ cm and $V_m = 23.6$ cm/s or 0.236 m/s
At $t_0 = 0$, $x_0 = 3$ cm and $v_0 = 0$. **(1)**

2) $T_0 = 2\pi\sqrt{\frac{m}{k}} \Rightarrow m = \left(\frac{T_0}{2\pi}\right)^2 k = \left(\frac{0.8}{2\pi}\right)^2 \times 15 = 0.243$ kg. **(¾)**

II – 1) (1¼)

t(s)	0	0.2	0.3
v(m/s)	0	- 0.236	-0.17
KE (J)	0	6.77×10^{-3}	3.51×10^{-3}
x(m)	0.030	0	-0.021
EPE (J)	6.75×10^{-3}	0	3.31×10^{-3}
ME (J)	6.75×10^{-3}	6.77×10^{-3}	6.82×10^{-3}

2) the mechanical energy is approximately the same $\Rightarrow$ it is constant. **(¼)**

Second Exercise (7 points)

A –

1) $\varphi = \vec{B}\,\vec{n}\, S\cos\alpha = -BS = -B\ell x$. **(¾)**

2) The magnetic flux varies, therefore an induced emf e appears across the extremities N and M of the rod **(½)**

3) $e = -\frac{d\varphi}{dt} = B\ell\frac{dx}{dt} = B\ell v$. **(¾)**

4) The circuit is open $\Rightarrow$ i = 0. **(½)**

5) $u_{NM} = e - ri$ (i = 0) $\Rightarrow u_{NM} = e > 0$,
The point N is positive and the point M is negative.
$U_{NM} = e = B\ell v$ **(2)**

B –

1) **a)** $\varphi_h = B_h S\cos 90^0 = 0$ **(½)**

b) $\varphi_V = B_V S\cos 0^0 = B_V \ell' x$

$e = -\frac{d\varphi}{dt} = -B_V\ell'\frac{dx}{dt} = -B_V\ell' v_1$. **(1)**

2) $|u_{NM}| = B_v\ell' v_1 \Rightarrow v_1 = \frac{0.36}{4\times10^{-5}\times30} = 300$ m/s. **(1)**

Third Exercise (6 points)

1) h: Planck's constant; c: speed of light in vacuum, e: elementary charge **(½)**

2) **a) i)** 330.3 nm ultraviolet domain;
568.8 nm, 589 nm and 615.4 nm visible domain;
819.5 nm and 1138.2 nm infra-red domain. **(¾)**

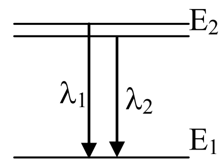
ii) Because this yellow light is much more intense than the others **(¼)**

b) It is polychromatic because it is made of several radiations of different frequencies **(¼)**

3) a) i) The discontinuity of the emission spectrum is justified by the discontinuous energy levels of the sodium atom. **(½)**

ii) $E = \frac{hc}{\lambda} = \frac{6.62\times10^{-34}\times3\times10^{8}}{589} = 3.37\times10^{-19}$ J or $E = \frac{3.37\times10^{-19}}{1.6\times10^{-19}} = 2.11$ eV. $E_1 + E = -5.14 + 2.11 = -3.03$ eV **(1¼)**

b) **(½)**



4) a) 1.01 + (-5.14) = - 4.13 eV , this energy level does not exist ⇒ the electron (a) does not interact with the atom.
3.03 + (-5.14) = - 2.11 eV , - 3.03 < - 2.11 < - 1.93 ev , ⇒ the electron (b) interacts with the atom. **(1)**

b) In case of the electron (a) the atom remains in the ground state.
In case of the electron (b) the atom attains level E_2. **(½)**

c) For the electron (b), K.E = 3.03 – (-3.03 + 5.14) = 0.92 eV **(½)**

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الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	

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

<u>First Exercise</u> (7 points)

Response of an (r, L, C) circuit to an alternating sinusoidal voltage

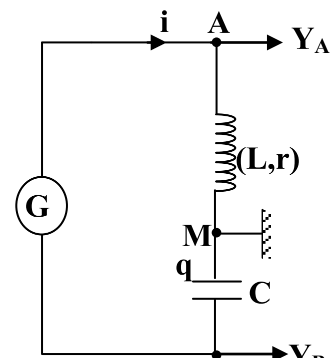


Fig. 1

Consider the series circuit that is represented in figure 1. This circuit is formed of a coil of inductance L and of resistance r, a capacitor of adjustable capacitance C , and a generator G delivering across its terminals an alternating sinusoidal voltage :

$$u_g = u_{AB} = 10\sqrt{3}\sin(\frac{200\pi}{3}t + \phi), \qquad (u_g \text{ in V, t in s}).$$

For a certain value of the capacitance C, the circuit carries an alternating sinusoidal current $i = \sin(\frac{200\pi}{3}t)$, (i in A, t in s). (Take $0.32\,\pi = 1$).

An oscilloscope, connected as shown in figure 1, displays the voltage u_{AM} across the coil on channel Y_A , and the voltage $u_{MB} = u_C$ across the capacitor on channel Y_B , the « INV » button of channel Y_B being pressed. On the screen of the oscilloscope, we observe the waveforms represented in figure 2.

The vertical sensitivity on both channels is $S_V = 5$ V/div.

1) Referring to figure 2 :

a) Determine the horizontal sensitivity of the oscilloscope;

b) Determine the amplitudes U_{AMmax} and U_{Cmax} of the voltages u_{AM} and u_C;

c) Show that the phase difference ϕ' between the voltages u_{AM} and u_C is $\frac{2\pi}{3}$ rad. Specify the voltage that leads the other.

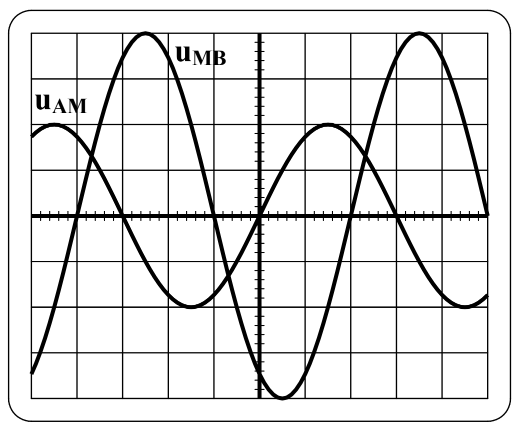


Fig.2

2) a) i) Write down the relation among i, C and $\frac{du_C}{dt}$.

ii) Show that the voltage u_C across the terminals of the capacitor is given by : $u_C = \frac{3}{200\pi C}\sin(\frac{200\pi}{3}t - \frac{\pi}{2})$.

iii) Deduce that the value of C is 240 μF.

b) i) Using figure 2 and the expression of u_C, determine the expression of u_{AM} as a function of time.

ii) Give the expression of u_{AM} in terms of r, i, L and $\frac{di}{dt}$.

iii) Using the preceding results, and by giving t two particular values, show that $r = 5\sqrt{3}\ \Omega$ and L = 0.024 H.

3) The relation $u_g = u_{AM} + u_{MB}$ is valid for any time t. Determine ϕ knowing that $-\frac{\pi}{2} < \phi_{rad} < \frac{\pi}{2}$.

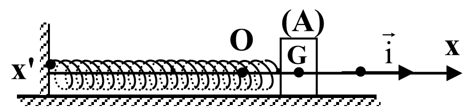
4) The value of C is made to vary. We notice that, for a certain value C' of C, the amplitude of i attains a maximum value.

a) Give the name of the physical phenomenon that thus took place.

b) Determine C'.

<u>Second Exercise</u> (7 points) Mechanical Oscillations

The aim of this exercise is to study different modes of oscillations of a horizontal elastic pendulum that is formed of a puck (A), of mass m = 200 g , and a spring of un-jointed turns of negligible mass and of stiffness k = 80 N/m.



The position of the center of mass G of (A) is defined, at an instant t, on an axis **x'x**, by its abscissa $x = \overline{OG}$; the velocity of G is then $\vec{V} = V\vec{i}$ where $V = x' = \frac{dx}{dt}$.

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

A – Free un-damped oscillations

At the instant $t_o = 0$, the center of mass G of (A) being at O (origin of abscissa), (A) is launched with a velocity $\vec{V}_0 = V_0\vec{i}$ (V_0 = 2.5 m/s). (A) thus moves along the support without friction.

1) Calculate the mechanical energy of the system [(A), spring, Earth].

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

b) Determine the differential equation that describes the motion of G.

c) Determine the value of the proper angular frequency ω_o and that of the proper period T_o of the oscillations.

3) The solution of the obtained differential equation has the form: $x = X_m \cos(\omega_o t + \varphi)$. Determine the values of the constants X_m and φ .

B – Free damped oscillations – Driving the oscillations

Now, G is at rest at O. We shift (A) by 12.5 cm from O and then we release it from rest at the instant $t_o = 0$. (A) thus performs pseudo-periodic oscillations of pseudo-period T .At the end of 10 oscillations, the amplitude of the motion becomes 12cm.

1) Calculate the variation in the mechanical energy of the system during these 10 oscillations.

2) The value of T is very close to that of T_o . Why?

3) In order to drive the oscillations of (A), a convenient apparatus provides the oscillator with an energy E during these 10 oscillations.

a) What does the term « driving the oscillations »mean?

b) Calculate the average power P_{av} furnished during these 10 oscillations.

Third Exercise (6 points) Photoelectric Effect

Given : speed of light in vacuum $c = 3\times10^{8}$ m/s ; 1 eV = 1.6×10^{-19} J.

A) The photoelectric effect was discovered by Hertz on 1887. The experiment represented in figure 1 may show evidence of this effect. A zinc plate is fixed on the conducting rod of an electroscope. The whole set-up is charged negatively. If we illuminate the plate by a lamp emitting white light rich with ultraviolet radiations (U.V), the leaves F and F' of the electroscope approach each other rapidly.

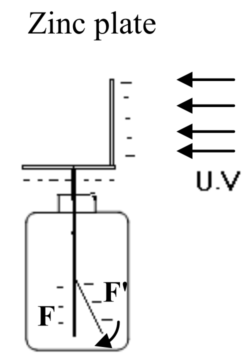


Fig.1

1) Due to what is the approaching of the leaves?
2) The photoelectric effect shows evidence of an aspect of light. What is this aspect?

B) The experiments performed by Millikan towards 1915, intended to determine the maximum kinetic energy K.E of the electrons emitted by metallic plates when illuminated by monochromatic radiation of adjustable wavelength λ in vacuum.

In an experiment using a plate of cesium, a convenient apparatus allows us to measure the maximum kinetic energy K.E of an emitted electron corresponding to the wavelength λ of the incident radiation.

The variation of K.E as a function of λ is represented in the graph of figure 2.

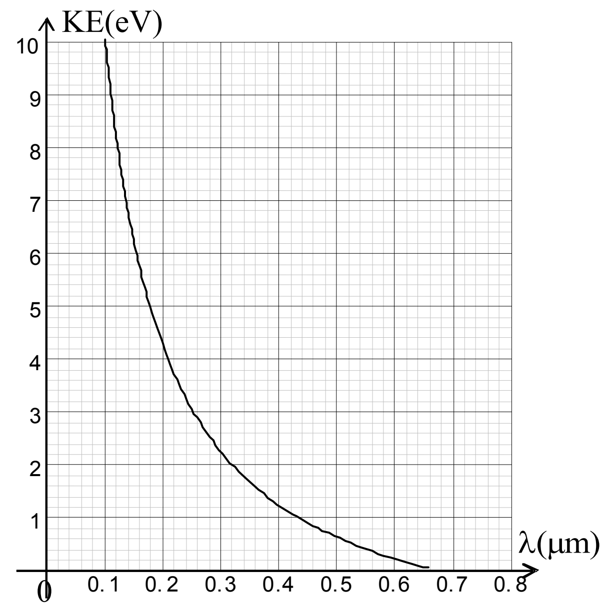


Fig.2

The aim of this part is to determine the value of Planck's constant h and that of the extraction energy W_0 of cesium.

1) Write down the expression of the energy E of an incident photon, of wavelength λ in vacuum, in terms of λ, h and c.
2) **a)** Applying Einstein's relation about photoelectric effect, show that the maximum kinetic energy K.E of an extracted electron may be written in the form $K.E = \frac{a}{\lambda} + b$, where a and b are constants.

   b) Deduce the expression of the threshold wavelength λ_0 of cesium in terms of W_0, h and c.
3) Referring to the graph:

   a) Give the value of the threshold wavelength λ_0 of cesium;

   b) Determine the value of W_0 and that of h.

First Exercise (7 points)

1) **a)** The angular frequency is $\omega = \frac{200\pi}{3} = \frac{2\pi}{T} \Rightarrow$ The period is T = 30 ms

The period extends over 6 divisions $\Rightarrow S_h = \frac{30}{6} = 5\ ms/div$. **(¾)**

b) $U_{bmax} = 2div \times 5V/div = 10$ V ; $U_{Cmax} = 4div \times 5V/div = 20V$. **(½)**

c) ϕ' corresponds to 2 div. $\Rightarrow \phi' = \frac{2\pi \times 2}{6} = \frac{2\pi}{3}$ rad. u_b leads u_c by ϕ' **(¾)**

2) **a) i)** $i = C\frac{du_C}{dt}$. **(¼)**

ii) $i = C\frac{du_C}{dt} \Rightarrow u_C = \frac{1}{C}$ pri.of $i = -\frac{1}{C}\frac{3}{200\pi}\cos(\frac{200\pi}{3}t)$

$\Rightarrow u_c = \frac{3}{200\pi C}\sin(\frac{200\pi}{3}t - \frac{\pi}{2})$. **(½)**

iii) $\frac{1}{C}\frac{3}{200\pi} = U_{Cmax} = 20\ V \Rightarrow C = 2.4\times10^{-4}$ F. **(½)**

b) i) $u_b = 10\sin(\frac{200\pi}{3}t - \frac{\pi}{2} + \frac{2\pi}{3}) = 10\sin(\frac{200\pi}{3}t + \frac{\pi}{6})$. **(½)**

ii) $u_b = ri + L\frac{di}{dt}$ **(½)**

iii) $u_b = ri + L\frac{di}{dt} = 10\sin(\frac{200\pi}{3}t + \frac{\pi}{6}) = r\sin(\frac{200\pi}{3}t) + \frac{200\pi}{3}L\cos(\frac{200\pi}{3}t)$.

For t = 0, we get : $5 = 0 + \frac{200\pi}{3}L \Rightarrow L = 24$ mH.

For $\frac{200\pi}{3}t = \frac{\pi}{2}$, we get : $10\times\frac{\sqrt{3}}{2} = r + 0 \Rightarrow r = 5\sqrt{3} = 8.66\ \Omega$. **(1)**

3) $u_g = u_b + u_C \Rightarrow 10\sqrt{3}\sin(\frac{200\pi}{3}t + \phi) = 10\sin(\frac{200\pi}{3}t + \frac{\pi}{6}) + 20\sin(\frac{200\pi}{3}t - \frac{\pi}{2})$.

For t = 0 , we get : $10\sqrt{3}\sin\phi = 5 - 20 = -15 \Rightarrow \sin\phi = -\frac{\sqrt{3}}{2} \Rightarrow \phi = -\frac{\pi}{3}$ rad **(¾)**

4) **a)** Current resonance **(¼)**

b) At resonance, $LC'\omega^2 = 1 \Rightarrow C' = \frac{1\times(3)^2}{0.024\times(200\pi)^2} = 9.6\times10^{-4}$ F. **(¾)**

Second Exercise (7 points)

A –

1) M.E = K.E + $P.E_e$ + $P.E_g$; $P.E_e = 0$, Since (A) is at O and $P.E_g = 0$ (reference)

Thus M.E = K.E = $\frac{1}{2}mV_0^2 = \frac{1}{2}(0.2)(2.5)^2 = 0.625$ J **(1)**

2) **a)** M.E = K.E + $P.E_e$ = $\frac{1}{2}mV^2 + \frac{1}{2}kx^2$ **(½)**

b) No friction $\Rightarrow$ M.E is conserved $\Rightarrow \frac{dM.E}{dt} = 0 \Rightarrow$

$\frac{1}{2}(m)(2)(V)(\ddot{x}) + \frac{1}{2}k(2)(V) = 0 \Rightarrow \ddot{x} + \frac{k}{m}x = 0$ **(½)**

c) $\omega_o = \sqrt{\frac{k}{m}} = 20$ rd/s and $T_o = 2\pi\sqrt{\frac{m}{k}} = 0.314$ s **(1)**

3) At max. elongation K.E = 0 Thus M.E = ½ k X^2_m

The conservation of M.E gives : 0.625 = ½ (80) X^2_m $\Rightarrow$ Xm = 0.125 m

$x = X_m\cos(\omega_o t + \varphi)$ and $V = -X_m\omega_o\sin(\omega_o t + \varphi)$

For t = 0 ; x = 0 $\Rightarrow \cos\varphi = 0 \Rightarrow \varphi_1 = \frac{\pi}{2}$ and $\varphi_2 = -\frac{\pi}{2}$

For t = 0 ; V = 2.5 m/s $\Rightarrow 2.5 = -0.125\times20\sin\varphi \Rightarrow \sin\varphi = -1$

$\Rightarrow \varphi = -\frac{\pi}{2}$ rd **(1½)**

B –

1) $\Delta M.E = \frac{1}{2}k(X^2_{2m} - X^2_{1m}) = -0.049$ J **(¾)**

2) Frictional forces are too small. **(¼)**

3) **a)** To provide the oscillator with the necessary energy needed to compensate for the losses and maintain its amplitude constant. **(½)**

b) The work supplied by the apparatus is : $E = |\Delta M.E|$

$\Rightarrow P_{Av} = \frac{0.049}{10\times0.314} = 0.016$ w. **(1)**

Third Exercise (6 points)

A –

1) The plate has excess of electrons; when the plate is exposed to U.V radiations, electrons are extracted, which explains the discharge of the electroscope. **(¾)**

2) Corpuscular aspect **(½)**

B – 1) $E = \frac{hc}{\lambda}$ **(¼)**

2) a) $E = K.E + W_0 \Rightarrow K.E = \frac{hc}{\lambda} - W_0 = \frac{a}{\lambda} + b$ with $a = hc$ and $b = -W_0$. **(1 ¼)**

b) $K.E = 0$, For $\frac{hc}{\lambda_0} - W_0 = 0 \Rightarrow \lambda_0 = \frac{hc}{W_0}$. **(1)**

3) a) $\lambda_0 = 0.66\ \mu m$ **(¾)**

b) Graphically we have :

For $\lambda = 0.18\ \mu m$, $K.E = 5\ eV \Rightarrow 5 \times 1.6 \times 10^{-19} = \frac{hc}{0.18 \times 10^{-6}} - W_0$

For $\lambda = 0.66\ \mu m$, $W_0 = \frac{hc}{0.66 \times 10^{-6}} \Rightarrow W_0 = 3 \times 10^{-19}$ J and $h = 6.6 \times 10^{-34}$ J.s **(1½)**

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الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	

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

First Exercise: *(6 points)* *Determination of the resistance of a resistor*

We intend to determine the resistance R of a resistor (R). We thus connect up the circuit represented in figure (1) that is formed of an ideal generator of e.m.f E = 5 V, the resistor (R), an uncharged capacitor (C) of capacitance C = 33 μF and a double switch (K).

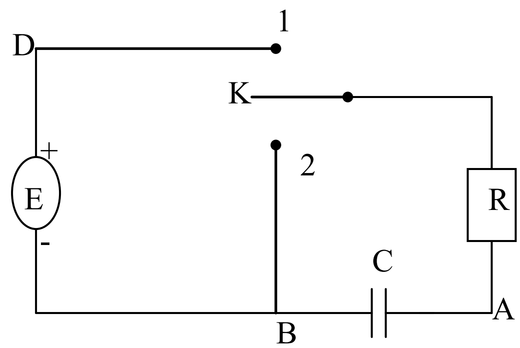


Fig. 1

A – Charging of the capacitor

1) We intend to charge the capacitor. To what position, 1 or 2, must then (K) be moved?

2) The circuit reaches a steady state after a certain time. Give then the value of the voltage u_{AB} across (C) and that of the voltage across (R).

B – Discharging of the capacitor

1) Draw a diagram of the circuit during the discharging of the capacitor and show on it the direction of the current it carries.

2) Derive the differential equation in $u_C = u_{AB}$ during the discharging.

3) The solution of this differential equation has the form :

$u_C = E\ e^{-\frac{t}{\tau}}$ (u_C in V , t in s)
where τ is a constant.

a) Determine the expression of τ in terms of R and C .

b) Determine the value of u_C at the instant $t_1 = \tau$.

c) Give, in terms of τ , the minimum duration needed at the end of which the capacitor is practically totally discharged.

d) Derive the expression of $\ell n\ u_C$, the natural logarithm of u_C , in terms of E , τ and t.

e) The diagram of figure 2 represents the variation of $\ell n\ u_C$ as a function of time .
Referring to the graph of figure 2, determine the value of R.

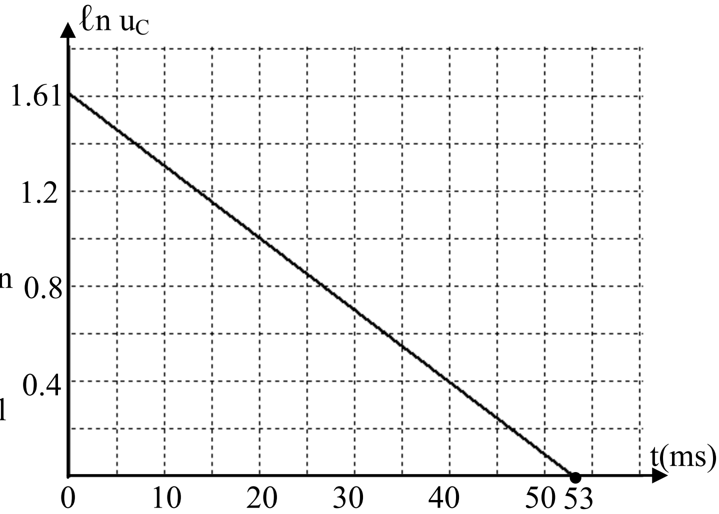
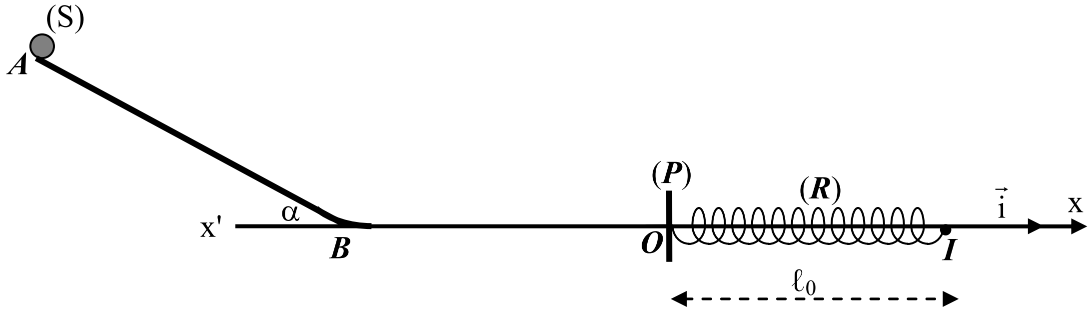


Fig. 2

Second Exercise: ***(7 points) Horizontal elastic pendulum***

A particle (S) of mass $m_1 = 100$ g can slide , without friction, on a track in a vertical plane, formed of a straight part AB , of length 10 cm, inclined by an angle $\alpha = 30^0$ with the horizontal and a straight horizontal part Bx.

A spring (R), of un-jointed turns and of negligible mass, of free length ℓ_0 and of stiffness k = 10 N/m, is placed horizontally on the part Bx. One end of the spring is fixed to the track at point I and the other end is fixed to a plate (P). (R) has a free length ℓ_0 and (P) is at point O of the horizontal part (figure below). The point O is taken as the origin of abscissas on the axis x'ox.



The particle (S) is released from rest at point A. The horizontal plane containing Bx is taken as a gravitational potential energy reference. Take $g = 10$ m/s^2.

A – Motion of the particle between A and O

1) Calculate the mechanical energy of the system [(S), Earth] at point A.

2) The mechanical energy of the system [(S), Earth] is conserved between the points A and O. Why?

3) (S) reaches point O with the velocity $\overrightarrow{V_0} = V_0\vec{i}$. Show that $V_0 = 1$ m/s.

B – Motion of the oscillator in two situations

I – First situation

The plate (P) has a negligible mass.

(S) collides with (P) and sticks to it thus forming a single body [(P), (S)] whose center of mass is G. At the instant $t_0 = 0$, G is at O. The system [(S), (P), spring] forms a horizontal mechanical oscillator. At an instant t, the abscissa of G is x and the algebraic measure of its velocity is v.

1) Write down the expression of the mechanical energy of the system [oscillator, Earth] in terms of m_1, x, v and k.

2) Derive the second order differential equation in x that governs the motion of G.

3) Deduce the nature of the motion of G and the expression of the period T_1 of this motion in terms of m_1 and k.

4) G , leaving O at the instant $t_0 = 0$, passes again through O for the first time at the instant t_1. Calculate the duration t_1.

II – Second situation

(P) is replaced by another plate (P') of mass $m_2 = 300$ g placed at O. Considering the initial conditions, (S) reaches (P'), just before collision , with the velocity $\overrightarrow{V_0} = V_0\vec{i}$ ($V_0 = 1$ m/s). Just after the head-on collision (collinear velocities) , (S) and (P') move separately, at the instant $t_0 = 0$, with the velocities $\overrightarrow{V_1}$ and $\overrightarrow{V_2} = V_2\vec{i}$ respectively where $V_2 = 0.5$ m/s.

1) Determine $\overrightarrow{V_1}$.

2) Show that the collision is elastic.

3) (P') leaves O at the instant $t_0 = 0$ then passes again through point O for the first time at the instant t_2. We notice that the durations t_1 and t_2 are related by $t_2 > t_1$. Justify.

Third Exercise: *(7 points)* *The radio-isotope polonium* $^{210}_{84}Po$

Given: $1u = 1.66 \times 10^{-27}$ kg = 931.5 MeV/c^2 ; 1 MeV = 1.6×10^{-13} J ;
Mass of some nuclei : m(Po) = 209.9829 u ; m(Pb) = 205.9745 u ; m(α) = 4.0026 u ;
$h = 6.63\times10^{-34}$ J.s ; $c = 3\times10^{8}$ m/s.

A – Decay of polonium 210

The polonium $^{210}_{84}Po$ is an α emitter. The daughter nucleus produced by this decay is the lead $^{A}_{Z}Pb$.

1) Determine Z and A specifying the laws used.

2) Calculate, in MeV and in J, the energy liberated by this decay.

3) The nucleus $^{210}_{84}Po$ is initially at rest. We suppose that the daughter nucleus $^{A}_{Z}Pb$ is obtained at rest and in the fundamental state. Deduce the kinetic energy of the emitted α particle.

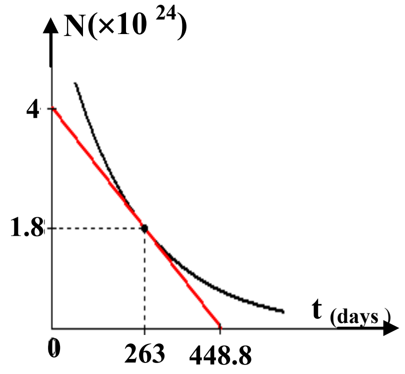
4) In general, the decay of $^{210}_{84}Po$ is accompanied by the emission of γ radiation.

a) Due to what is the emission of γ radiation?

b) The emitted γ radiation has the wavelength $\lambda = 1.35\times10^{-12}$ m in vacuum. Using the conservation of total energy, determine the kinetic energy of the emitted α particle.

B – Radioactive period of polonium 210

The adjacent figure shows the curve representing the variations with time t of the number N of the nuclei present in the radioactive sample $^{210}_{84}Po$, this number being called N_0 at the instant $t_0 = 0$. The same figure shows also the tangent to that curve at the instant $t_1 = 263$ days.



1) Write down the expression of N as a function of t and specify what does each term represent.

2) The activity of the radioactive sample is given by: $A = -\dfrac{dN}{dt}$.

a) Define the activity A.

b) Using the given on the figure above, determine the activity A of the sample at the instant $t_1 = 263$ days.

3) Deduce the value of the radioactive constant and the value of the half-life (period) of polonium 210.

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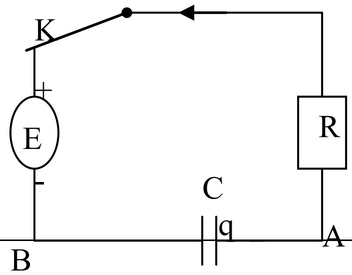
First exercise (6 points)

Part of the Q	Answer	Mark
A.1	We have to move the switch (K) to position 1.	
A.2	After certain time $\Rightarrow$ uc = E = 5 V, $u_R = 0$	
B.1	B.1 	
B.2	$q = C\,u_c$, therefore $i = -\,C\,\frac{du_C}{dt}$ $u_{AB} = Ri = u_c \Rightarrow -\,Ri + u_c = 0$ $RC\,\frac{du_C}{dt} + u_c = 0.$	
B.3.a	$\frac{du_C}{dt} = -\,\frac{1}{\tau}\,E e^{\frac{-t}{\tau}}\quad -RC\,\frac{1}{\tau}\,E e^{\frac{-t}{\tau}} + E e^{\frac{-t}{\tau}} = 0$ $\Rightarrow \tau = RC$	
B.3.b	$t_1 = \tau \Rightarrow$ uc = 1,85 V.	
B.3.c	$t_{min} = 5\,\tau$	
B.4.d	$\ell n\, u_c = -\frac{t}{\tau} + \ell n\, E$	
B.3.e	Slope $= -\,\frac{1}{\tau} = -\,\frac{1.61}{0.053}$ but $= RC \Rightarrow R = \frac{\tau}{C} = 10^3\ \Omega.$	

Second exercise (7 points)

Part of the Q	Answer	Mark
A.1	$ME_A = KE_A + GPE_A = 0 + m_1gh = m_1g(AB\sin\alpha) = 0.1\times 10\times 0.1\times 0.5$ $ME_A = 0.05$ J	
A.2	friction is negligible	
A.3	$ME_A = ME_O = GPE_O + KE_O = 0 + ½m_1V^2 \Rightarrow V = 1$ m/s.	
B.I.1	$ME = ½\, m_1v^2 + ½\, kx^2$	
B.I.2	$\frac{dME}{dt} = 0 = m_1vx'' + kxv \Rightarrow x'' + \frac{k}{m}x = 0$	
B.I.3	The form is $x'' + \omega_0^2 x = 0$ then Simple harmonic motion $\omega_1 = \sqrt{\frac{k}{m_1}} \Rightarrow T_1 = 2\pi\sqrt{\frac{m_1}{k}}$.	
B.I.4	$t_1 = \frac{T_1}{2} = \pi\sqrt{\frac{m_1}{k}} = \pi\sqrt{\frac{0.1}{10}} = 0.314$ s	
B.II.1	The linear momentum is conserved $m_1\vec{V} + \vec{0} = m_1\vec{V_1} + m_2\vec{V_2} \Rightarrow m_1V = m_1V_1 + m_2V_2$ $\Rightarrow m_1(V-V_1) = m_2V_2 \Rightarrow V_1 = -0{,}5$ m/s $\Rightarrow \vec{V_1} = -0{,}5\ \vec{i}$	
B.II.2	$KE_{Before} = ½\, m_1V_0^2 + 0 = 0{,}05$ J ; $KE_{After} = ½\, m_1V_1^2 + ½\, m_2V_2^2 = 0{,}05$ J $KE_{Before} = KE_{After} \Rightarrow$ Elastic collision	
B.II.3	The period increases with the mass $\Rightarrow T_2 > T_1 \Rightarrow t_2 > t_1$	

Third exercise (7 points)

Part of the Q	Answer	Mark
A.1	${}^{210}_{84}Po \longrightarrow {}^{206}_{82}Pb + {}^{4}_{2}He$; Using the laws of conservation of charge and mass numbers, Z = 82 and A = 206.	
A.2	$E = \Delta mc^2$, $\Delta m = 209.9829 - (4.0026+205.9745) = 0.0058$ u , … $E = (0.0058)(931.5 MeV/c^2)c^2 = 5.4 MeV = 5.4\times1.6\times10^{-13}$ J $E = 8.64\times10^{-13}$ J	
A.3	$E(\gamma) = 0 \Rightarrow KE_{(\alpha)} = E = 5.4 MeV = 8.64\times10^{-13}$ J	
A.4.a	If the obtained daughter nucleus is in an excited state and when drops to the ground state it emits γ rays	
A.4.b	$E(\gamma) = hc/\lambda = 1.4733\times 10^{-13}$ J = 0.92 MeV ; $m(Po)c^2 + 0 = m(Pb)c^2 + 0 + m(_\alpha)c^2 + KE_{(\alpha)} + E(\gamma)$ $\Rightarrow E = \Delta mc^2 = KE_{(\alpha)} + E(\gamma) \Rightarrow KE_\alpha = 5.4 - 0.92 = 4.48$ MeV.	
B.1	$N = N_o e^{-\lambda t}$, N_o being respectively the number of nuclei present at $t_0 = 0$ and at t ,λ is the radioactive constant and t is the time .	
B.2.a.i	Activity is the number of decayed nuclei per unit time.	
B.2.a.ii	A = -(slope of the curve) = $\frac{4\times10^{24}}{448.8} = 8.91\times 10^{21}$ decays /day	
B.2.b	$A = \lambda N$ then $\lambda = A/N = 0.00495$ day^{-1} ; $T = \frac{\ln 2}{\lambda} = \frac{0.69}{0.00495} = 140$ days	

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

First Exercise: (7 points) *Study of an RLC series circuit*

The circuit of (fig. 1) is formed of a coil(L, r) , a resistor of resistance $R = 50\ \Omega$ and a capacitor of capacitance $C = 64\ \mu F$ all connected in series across a generator G that maintains , across its terminals A and D, an alternating sinusoidal voltage of adjustable frequency f and of constant effective value U. The circuit thus carries an alternating sinusoidal current i whose expression as a function of time is given by:
$i = I_m \sin(2\pi f t)$ (i in A, t in s).
An oscilloscope, conveniently connected, allows us to display the voltage u_{BM} across the coil on channel Y_1 , and the voltage u_{MD} across the resistor on channel Y_2. We obtain the waveforms (a) and (b) represented in figure 2.
The vertical sensitivity on both channels is 2V/div.
The horizontal sensitivity is 5 ms/div.
Take: $0.32\pi = 1$.

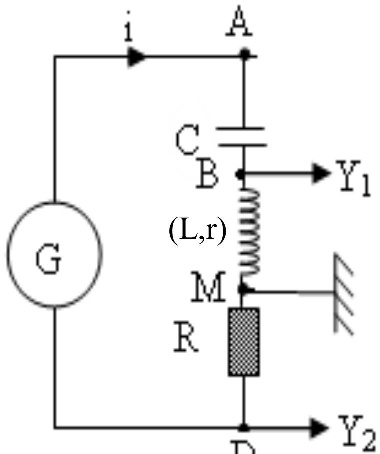


Fig.1

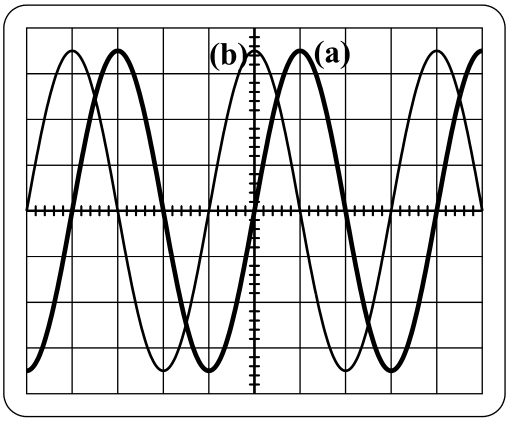


Fig.2

1) The button "INV" of channel Y_2 is pressed. Why?
2) Which one of the two waveforms represents the voltage u_{BM}? Why?
3) Referring to figure 2,
   a) calculate f ;
   b) i) calculate the phase difference between the voltages u_{BM} and u_{MD};
      ii) deduce that the coil has no resistance;
   c) calculate the maximum voltage $U_{BM(max)}$ across the coil;
   d) calculate the maximum voltage $U_{MD(max)}$ across the resistor.
4) Show that the expression of the voltage u_{MD} is of the form:
   $u_{MD} = 7 \sin(100\pi t)$ (u_{MD} in V, t in s).
5) Determine , as a function of time, the expression of :
   a) the current i ;
   b) the voltage u_{BM} ;
   c) the voltage u_{AB} across the capacitor.
6) a) Applying the law of addition of voltages , determine the expression of the voltage u_{AD} across the generator as a function of time.
   b) i) Deduce that the average electric power P consumed in the circuit is maximum.
      ii) Calculate P.

Second Exercise: *(6 points)* **Photoelectric effect**

A metallic plate, covered with a layer of cesium, is illuminated with a monochromatic luminous beam of wavelength $\lambda = 0.45 \times 10^{-6}$ m in vacuum.
The work function (extraction energy) of cesium is $W_0 = 1.88$ eV.
A convenient apparatus (D) is used to detect the electrons emitted by the illuminated plate.

Given: Planck's constant $h = 6.6 \times 10^{-34}$ J.s; speed of light in vacuum $c = 3 \times 10^8$ m/s;
1 eV = 1.6×10^{-19} J; elementary charge $e = 1.6 \times 10^{-19}$ C.

1) What aspect of light does the phenomenon of photoelectric effect show evidence of ?

2) Define the term "work function" of a metal.

3) The luminous beam illuminating the metallic plate is formed of photons.

a) ***i)*** Write down the expression of the energy E of a photon in terms of h, c and λ.

ii) Calculate, in eV, the energy of an incident photon.

b) (D) detects electrons emitted by the plate.

Why do we have an emission of electrons by the plate?

c) Calculate, in eV, the maximum kinetic energy of an emitted electron.

4) The luminous power P received by the plate is 10^{-3} W, and the emitted electrons form a current $I = 5\ \mu A$.

a) Calculate the number n of photons received by the plate in one second.

b) Knowing that the current I is related to the number N of the electrons emitted per second and to the elementary charge e by the relation: $I = N \times e$. Calculate N.

c) ***i)*** Calculate the quantum efficiency $r = \frac{N}{n}$.

ii) Deduce that the number of effective photons in one second is relatively small.

d) We increase the luminous power P received by the plate without changing the wavelength λ.

Would the current increase or decrease? Why?

Third Exercise: *(7 points)* **Resistive force on a car**

A car of mass M = 1500 kg moves on a straight horizontal road; its center of gravity G is moving on the axis $(O, \vec{i})$.

The car is acted upon by the forces:

- its weight;
- the normal reaction of the road;
- a constant motive force $\vec{F}_m = F_m \vec{i}$ where $F_m = 3500$ N;
- a resistive force $\vec{F}_f = -F_f \vec{i}$.

In order to determine F_f, we measure the speed V of the car at different instants, separated by equal time intervals each being $\tau = 1$ s.

A – Value of $\vec{F}_f$ between the instants $t_0 = 0$ and $t_5 = 5$ s

The results of the obtained recordings are tabulated as follows:

Instant	$t_0 = 0$	$t_1 = \tau$	$t_2 = 2\tau$	$t_3 = 3\tau$	$t_4 = 4\tau$	$t_5 = 5\tau$
Position	O	G_1	G_2	G_3	G_4	G_5
V(m/s)	0	2	4	6	8	10

1) Using the scale below, draw the curve representing the variation of the speed V as a function of time.
- 1 cm on the axis of abscissas represents 1 s;
- 1 cm on the axis of ordinates represents 1 m/s.

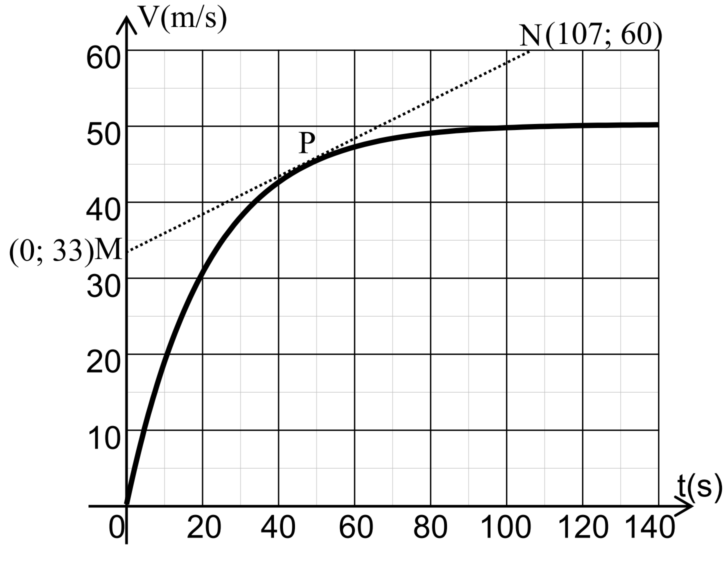
2) Show that the relation between the velocity $\vec{V} = V\vec{i}$ at a time t has the form $\vec{V} = bt\vec{i}$ where b is a constant.

3) ***a)*** the constant b is a characteristic physical quantity of motion. Give its name .
b) Calculate its value.

4) Applying Newton's second law,
a) show that F_f is constant between $t_0 = 0$ and $t_5 = 5$ s;
b) calculate the value F_f of $\vec{F}_f$.

B – Variation of F_f between the instants $t_5 = 5$ s and $t = 140$ s

In reality, the measurement of the speed between the instants $t_0 = 0$ and t = 140 s allows us to plot the graph of the adjacent figure.



1) Show that the part of this graph between the instants $t_0 = 0$ and $t_5 = 5$ s is in agreement with the graph of part A.

2) We draw the tangent MN to the curve at the point P at the instant t_P where $V_P = 45$ m/s.
a) Determine the value of the acceleration at the instant t_P.
b) Deduce the value of F_f at the instant t_P.

3) Starting from the instant 100s, V attains a limiting value of $V_\ell = 50$ m/s. Calculate then the value of F_f.

4) Indicate the time interval during which F_f increases.

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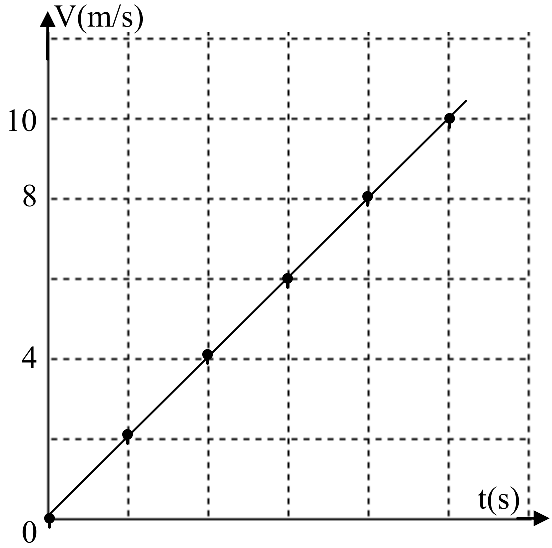
First Exercise (7 points)

Part of the Ex.	Answer	Mark
1	To display u_{MD} and not u_{DM}	0.25
2	The voltage of a coil leads the current i, thus (b) represents u_{BM}.	0.5
3.a	The period T corresponds to 4 div, thus T = 4 div×5 ms/div = 20 ms. $f = \frac{1}{T} = \frac{1}{20\times10^{-3}} = 50$ Hz	0.75
3.b.i	4 divisions correspond to a difference in phase 2π rad. 1 division corresponds to φ_1 rd, thus $\lvert\varphi_1\rvert = \frac{2\pi\times1}{4} = \frac{\pi}{2}$ rad.	0.75
3.bii	Phase difference between u_{BM} and i being $\frac{\pi}{2}$ rad, thus the coil has a negligible resistance	0.5
3.c	$u_{BM(max)}$ = 3.5 div×2 V/div = 7 V.	0.25
3.d	$u_{MD(max)}$ = 3.5 div×2 V/div = 7 V	0.25
4	u_{MD} is in phase with i $\Rightarrow u_{MD} = u_{MD(max)}\sin 2\pi ft = 7\sin(100\pi t)$	0.5
5.a	$u_{MD(max)} = RI_m \Rightarrow I_m = \frac{7}{50} = 0.14$ A $\Rightarrow i = 0.14\sin(100\pi t)$	0.5
5.b	$u_{BM} = u_{BM(max)}\sin(100\pi t + \frac{\pi}{2}) = 7\sin(100\pi t + \frac{\pi}{2}) = 7\cos(100\pi t)$	0.5
5.c	$i = C \Rightarrow \frac{du_{AB}}{dt}$ $U_{AB} = \frac{1}{C}$ primitive of $I = -\frac{0.14}{100\pi C}\cos(100\pi t)$. $i = -7\cos(100\pi t)$.	0.75
6.a	$u_{AD} = u_{AB} + u_{BM} + u_{MD}$ $u_{AD} = -7\cos(100\pi t) + 7\cos(100\pi t) + 7\sin(100\pi t)$. $u_{AD} = 7\sin(100\pi t)$	0.5
6.b.i	The phase difference between $u_{AD} = u_G$ and i is null, the circuit is the seat of current resonance where I_m is in this case has a maximum value. $\cos\varphi = 1$ is max. Thus P is max.	0.5
6.b.ii	$P = UI = \frac{0.14}{\sqrt{2}}\times\frac{7}{\sqrt{2}} = 0.49$ W.	0.5

Second Exercise: (6 points)

Part of the EX.	Answer	Mark
1	Corpuscular aspect of light	0.25
2	The extraction energy of a substance is the minimum energy needed to extract an electron from the substance	0.5
3.a.i	$E = \frac{hc}{\lambda}$	0.25
3.a.ii	$E = \frac{6.6\times10^{-34}\times3\times10^{8}}{0.45\times10^{-6}} = 44\times10^{-20}$ J = 2.75 eV.	0.75
3.b	Since E = 2.75 eV is > W_0 = 1.88 eV	0.5
3.c	Einstein's relation about photoelectric effect is: $E = W_0 + KE \Rightarrow KE = 2.75 - 1.88 = 0.87$ eV	0.75
4.a	$P = nE \Rightarrow n = \frac{1\times10^{-3}}{44\times10^{-20}} = 227\times10^{13}$ photons/s.	0.75
4.b	$N = \frac{5\times10^{-6}}{1.6\times10^{-19}} = 3.125\times10^{13}$ electrons/s	0.5
4.c.i	r = 0.014 = 1.4 %.	0.5
4.c.ii	r is small $\Rightarrow$ the number of effective photons per second is small	0.25
4.d	$P = nE = n\frac{hc}{\lambda}$;if we increase P keeping λ constant, $\Rightarrow$ n increases $\Rightarrow$N = number of emitted electrons increase But $I = N \times e \Rightarrow$ I increases.	1

Third Exercise: (7 points)

Part of the Ex.	Answer	Mark
A.1		1
A.2	The graph is a straight line passing through the origin, in agreement with the function $\vec{V} = bt\vec{i}$ where b is a constant	0.5
A.3.a	b the acceleration of the motion;.	0.5
A.3.b	$b = \frac{\Delta V}{\Delta t} = \frac{10-0}{5} = 2\,m/s^2$.	1
A.4.a	$\sum \vec{F}_{ext} = \frac{d\vec{P}}{dt} \Rightarrow \frac{d\vec{P}}{dt} = M\vec{g} + \vec{R} + \vec{F}_m + \vec{F}_f$. Projection along the horizontal: $M\frac{dV}{dt} = F_m - F_f \Rightarrow Mb = F_m - F_f$; F_m = const. M = const. and b = const. $\Rightarrow F_f$ = constant	1
A.4.b	$\Rightarrow F_f = F_m - mb$ $F_f = 3500 - 1500\times2 = 500$ N	0.5
B.1	For V < 10 m/s , the part of the curve is a straight line	0.5
B.2.a	$a = \frac{dV}{dt}$ is the slope of the tangent. $a = \frac{60-33}{107-0} = 0.25\ m/s^2$	0.75
B.2.b	$F_f = 3500 - 1500\times 0.25 = 3125$ N.	0.5
B.3	$a = 0 \Rightarrow F_f = F_m = 3500$ N	0.5
B.4	5 s < t < 100 s	0.25

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الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ثلاث ساعات	

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

First Exercise (7.5 points) *Moment of inertia of a rod*

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.

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.

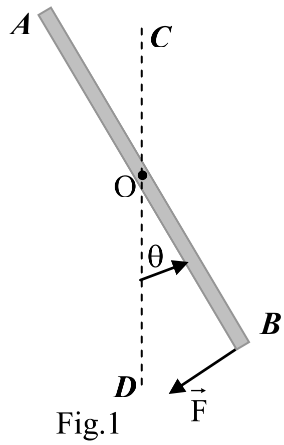


Fig.1

A – First method

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 $\mathcal{M}$ = 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 $\mathcal{M}$.
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 – Second method

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.

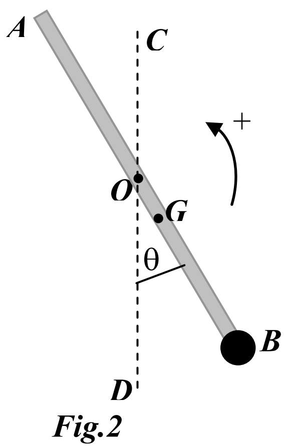


Fig.2

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.

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

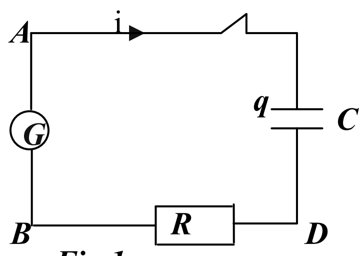


Fig 1

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.

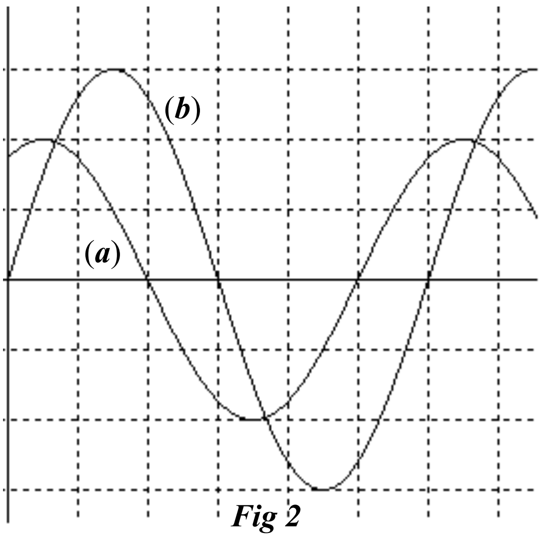


Fig 2

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 $\nu = 6.163 \times 10^{14}$ 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.

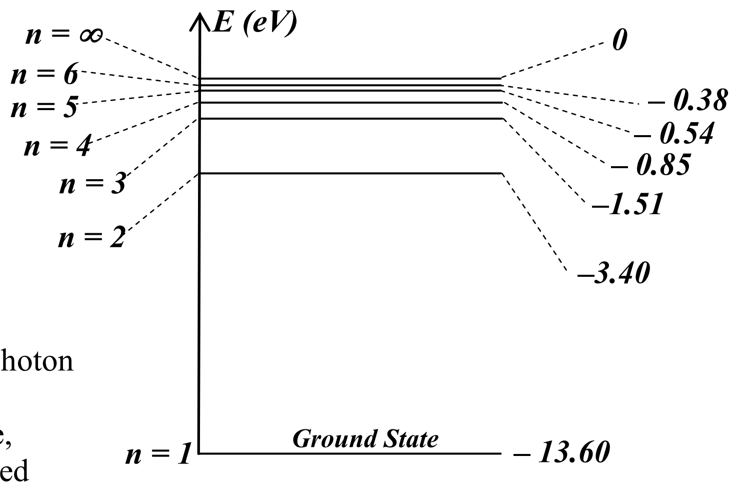
2) Determine the maximum kinetic energy of an emitted electron.

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 $u_{AM} = U_0$.

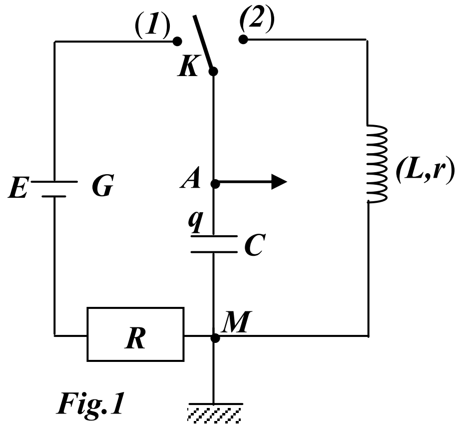


Fig.1

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.
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.

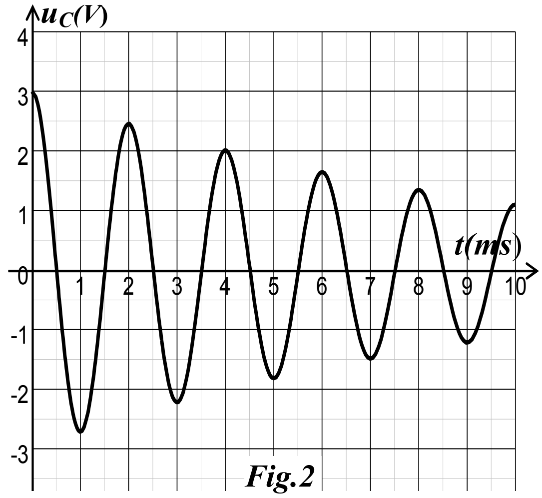


Fig.2

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).

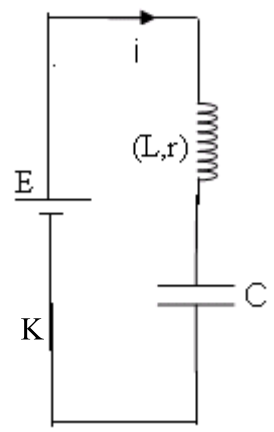


Fig.3

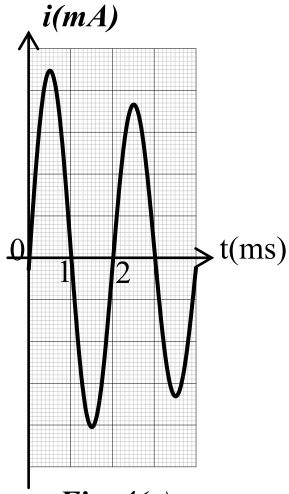


Fig. 4(a)

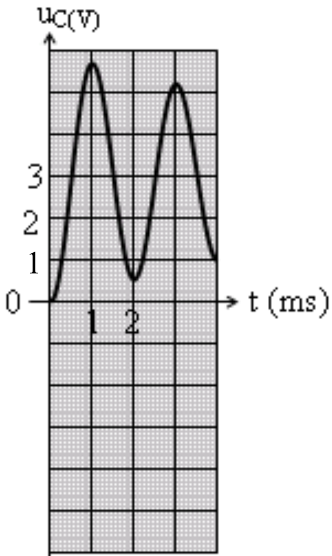


Fig. 4(b)

   - ***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 : $0 \leq t \leq 0.5$ ms ; 0.5 ms $\leq t \leq 1$ ms ; 1 ms $\leq t \leq 1.5$ 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.

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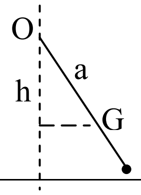
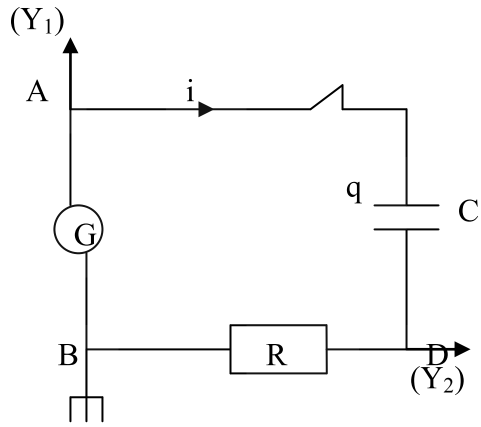
الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ثلاث ساعات	مشروع معيار التصحيح

First exercise (7.5 points)

Part of the Q	Answer	Mark
A.1.a	$\Sigma M = M(\text{weight}) + M(\text{reaction of the axis}) + M$ The weight & the reaction meet the axis of rotation: $\Sigma M = 0 + 0 + M = M$	0.75
A.1.b	$\frac{d\sigma}{dt} = \Sigma M = M = I_0 . \theta'' = \text{cte} \Rightarrow \theta'' = \text{cte}$, initial speed being null $\Rightarrow$ the rotational motion of the rod is uniformly accelerated.	0.5
A.1.c	$\theta'' = \text{cte} = \frac{M}{I_0} \Rightarrow \theta' = \frac{M\,t}{I_0}$. $\sigma = I_0\,\theta' = M\,t$	0.5
A.2	$\theta' = 2\pi N \Rightarrow$ At t_1: $2\pi N I_0 = M\,t_1 \Rightarrow I_0 = \frac{0.1\times 10}{2\pi\times 8} = 1.99\times 10^{-2} \approx 0.02\ \text{kg.m}^2$	1
B.1.a	$a = \frac{m\times 0 + m'\frac{\ell}{2}}{(m+m')} = \frac{m'\ell}{2(m+m')}$.	0.5
B.1.b	$I = I_0 + m'\frac{\ell^2}{4}$	0. 5
B.2	$ME = KE + PE_g = \frac{1}{2} I(\theta')^2 - (m + m')g\,h$ $h = a\cos\theta \Rightarrow ME = \frac{1}{2}I(\theta')^2 - (m + m')g\,a\cos\theta$.  	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	$T = 1.732\ \text{s} = \sqrt{3}\ \text{s} \Rightarrow 3 = \frac{8I_0 + 0.32}{0.16} \Rightarrow I_0 = \frac{0.16}{8} = 0.02\ \text{kg.m}^2$.	0.75

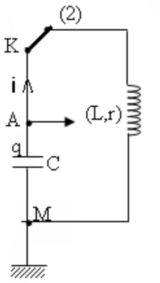
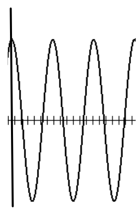
Second exercise (7.5 points)

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	$u_C = \frac{1}{C}\int i dt \Rightarrow u_C = -\frac{I\sqrt{2}}{C\omega}\cos(\omega t + \varphi)$.	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	$tg\varphi = \frac{1}{RC\omega} = \sqrt{3}$ $\Rightarrow$ **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	$W_0 = ½ CE^2 = 4{,}5\times 10^{-6}$ J.	0.50
B.1.a	Arbitrary direction for i 	0.50
B.1.b	$u_C = ri + L\frac{di}{dt}$, $i = -\frac{dq}{dt} = -C\frac{du_C}{dt}$ => $\mathbf{u_C = -LC\ u''_C => LC\ u''_C + u_C = 0 => u''_C + \frac{1}{LC}\ u_C = 0.}$	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 ms $\le t \le$ 1 ms u_C increases and i decreases $\Rightarrow$ the coil gives energy to the capacitor.	0.25
B.3.c.ii	For 1ms $\le t \le$ 1.5 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 ms : u_C increase and i increases $\Rightarrow$ no exchange of energy between the coil and the capacitor.	0.25

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الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	

<u>This exam is formed of three exercises in three pages.</u>
<u>The use of a non-programmable calculator is allowed</u>

First Exercise *(6 ½ points)*

Determination of the inductance of a coil

In order to determine the inductance L of a coil of negligible resistance, we connect this coil in series with a resistor of resistance R = 10 Ω across the terminals of a generator G (Fig. 1). The generator G delivers an alternating sinusoidal voltage $u_{AD} = u_G = U_m \cos\omega t$ (u_G in V, t in s).
The circuit thus carries a current i.

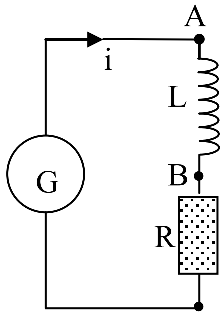


Fig.1

1) Redraw a diagram of figure (1), showing on it the connections of an oscilloscope so as to display the voltage u_G across the terminals of the generator and the voltage $u_R = u_{BD}$ across the terminals of the resistor.

2) Which of these two voltages represents the image of i ?
Justify your answer

3) In figure 2, the waveform (1) represents the variation of u_G as a function of time.
- Horizontal sensitivity: 5 ms/div.
- Vertical sensitivity on both channels: 1 V/div.

a) Specify, with justification, which of the waveforms, (1) or (2), leads the other.

b) Determine:
i. The phase difference between these two waveforms.
ii. The angular frequency ω.
iii. The maximum value U_m of the voltage across G.
iv. The amplitude I_m of i.

c) Write down the expression of i as a function of time t.

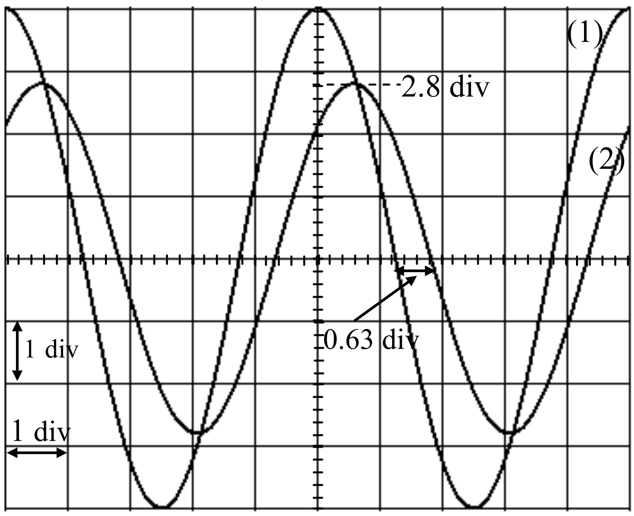


Fig.2

4) Determine the voltage $u_{AB} = u_L$ across the terminals of the coil as a function of L and t.

5) Determine the value of L by applying the law of addition of voltages and by giving t a particular value.

Second Exercise *(7 points)*

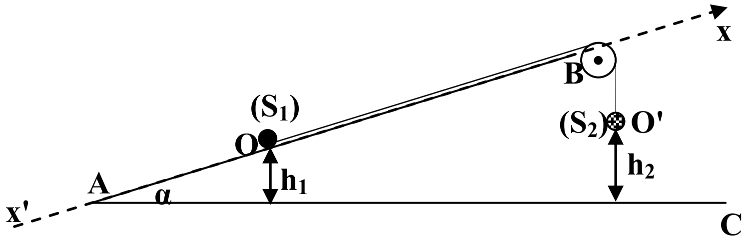
Acceleration of a particle

The object of this exercise is to determine the expression of the magnitude of the acceleration of a particle using two methods. The apparatus used is formed of two particles (S_1) and (S_2) of respective masses m_1 and m_2, fixed at the extremities of an inextensible string passing over the groove of a pulley. (S_1), (S_2), the string and the pulley form a mechanical system (S).

The string and the pulley have negligible mass.

(S_1) may move on the line of greatest slope AB of an inclined plane that makes an angle α with the horizontal AC and (S_2) hangs vertically.

At rest, (S_1) is found at point O at a height h_1 above AC and (S_2) is found at O' at a height h_2 (adjacent figure).



At the instant $t_0 = 0$, we release the system (S) from rest. (S_1) ascends on AB and (S_2) descends vertically.

At an instant t, the position of (S_1) is defined by its abscissa $x = \overline{OS_1}$ on an axis x'Ox confounded with AB, directed from A to B.

Take the horizontal plane containing AC as a gravitational potential energy reference.

Neglect all the forces of friction.

1) Energetic method

a) Write down, at the instant $t_0 = 0$, the expression of the mechanical energy of the system [(S), Earth] in terms of m_1, m_2, h_1, h_2 and g.

b) At the instant t, the abscissa of (S_1) is x and the algebraic value of its velocity is v. Determine, at that instant t, the expression of the mechanical energy of the system [(S), Earth] in terms of m_1, m_2, h_1, h_2 , x, v, α and g.

c) Applying the principle of conservation of mechanical energy, show that :

$$v^2 = \frac{2(m_2 - m_1 \sin\alpha)gx}{(m_1 + m_2)}.$$

d) Deduce the expression of the value a of the acceleration of (S_1).

2) Dynamical method

a) Redraw a diagram of the figure and show, on it, the external forces acting on (S_1) and on (S_2). (The tension in the string acting on (S_1) is denoted by $\vec{T}_1$ of magnitude T_1 and that acting on (S_2) is denoted by $\vec{T}_2$ of magnitude T_2).

b) Applying the theorem of the center of mass $\Sigma\vec{F}_{ext} = m\vec{a}$,on each particle, determine the expressions of T_1 and T_2 in terms of m_1 , m_2 , g , α and a .

c) Knowing that $T_1 = T_2$, deduce the expression of a.

Third Exercise (6 ½ points)

Provoked Nuclear Reactions

The object of this exercise is to compare the energy liberated per nucleon in a nuclear fission with that liberated in a nuclear fusion.

Given:

Symbol	$^{1}_{0}n$	$^{2}_{1}H$	$^{3}_{1}H$	$^{4}_{2}He$	$^{235}_{92}U$	$^{94}_{Z}Sr$	$^{A}_{54}Xe$
Mass in u	1.00866	2.01355	3.01550	4.0015	234.9942	93.8945	138.8892

$1u = 931.5\ MeV/c^2$

A – Nuclear fission

The fission of uranium 235 is used to produce energy.

1) The fission of one uranium 235 nucleus takes place by bombarding this nucleus by a slow (thermal) neutron of kinetic energy around 0.025 eV .The equation of this reaction is written as :

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{94}_{Z}Sr + ^{A}_{54}Xe + 3\,^{1}_{0}n$$

a) Calculate A and Z specifying the laws used.
b) Show that the energy E liberated by the fission of one uranium nucleus is 179.947 MeV.
c) ***i)*** The number of nucleons participating in this reaction is 236. Why?
ii) Calculate then E_1, the energy liberated per nucleon participating in this fission reaction.

2) Each of the obtained neutrons has an average kinetic energy $E_0 = \frac{E}{100}$.

a) In this case, the obtained neutrons do not, in general, provoke fission. Why?
b) What then should be done in order to obtain a fission reaction?

B – Nuclear fusion

Nowadays, many researches are performed in order to produce energy by nuclear fusion. The most accessible is the reaction between a deuterium nucleus $^{2}_{1}H$ and a tritium nucleus $^{3}_{1}H$.

1) The deuterium and the tritium are two isotopes of hydrogen. Write down the symbol of the third isotope of hydrogen.
2) Write down the fusion reaction of a deuterium nucleus with a tritium nucleus knowing that this reaction liberates a neutron and a nucleus $^{A}_{Z}X$. Calculate Z and A and give the name of the nucleus $^{A}_{Z}X$.
3) Show that the energy liberated by this reaction is $E' = 17.596$ MeV.
4) Calculate E'_1 the energy liberated per nucleon participating in this reaction.

C – Conclusion

Compare E_1 and E'_1 and conclude.

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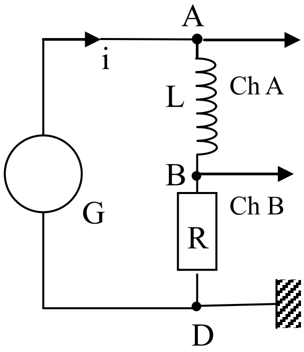
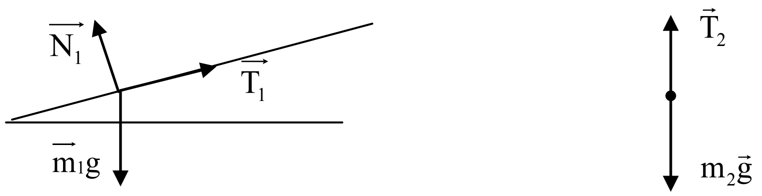
الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	مشروع معيار التصحيح

First exercise (6 ½ points)

Part of the Q.	Answer	Mark
1		½
2	$u_R = Ri$, u_R is proportional to i.	½
3-a	u_1 becomes zero before u_2, thus $u_1 = u_G$ leads i ($u_2 = u_R$ represents i).	½
3-b-i	$T \leftrightarrow 5$ div $\leftrightarrow 2\pi$ rad 0.63 div $\leftrightarrow \varphi \Rightarrow \varphi = 2\pi\times\dfrac{0.63}{5} = 0.79$ rd	¾
3-b-ii	T = 5 (div)×5 ms/div = 25 ms $\omega = \dfrac{2\pi}{T} = 251.3$ rad/s	½
3-b-iii	Um = 4 (div)× 1 V/div = 4 V	½
3-b-iv	$U_{Rm} = 2.8\times1 = 2.8$ V $\Rightarrow I_m = \dfrac{U_{Rm}}{R} = \dfrac{2.8}{10} = 0.28$ A	¾
3-c	i lags u_G by 0.79 rad; $i = I_m \cos(\omega t - 0.79)$ $i = 0.28 \cos(80\pi t - 0.79)$	½
4	$u_L = L\dfrac{di}{dt} = -70.37L \sin(80\pi t - 0.79)$	1
5	$u_G = u_R + u_L = Ri + u_L$ $4 \cos(80\pi t) = 2.8 \cos(80\pi t - 0.79) - 70.37L \sin(80\pi t - 0.79)$ For t = 0 ; L = 0.04 H = 40 mH.	1

Second exercise (7 points)

Part of the Q	Answer	Mark
1.a	$M.E = K.E_1 + P.E_{g1} + K.E_2 + P.E_{g2} = 0 + m_1gh_1 + 0 + m_2gh_2$	½
1.b	$M.E = KE_1 + P.E_{g1} + K.E_2 + P.E_{g2}$ $M.E = \frac{1}{2} m_1v^2 + m_1g (h_1+ x\sin\alpha)+ \frac{1}{2} m_2v^2 + m_2g (h_2 - x)$	1
1.c	$\frac{1}{2} m_1v^2 + m_1g (h_1+ x\sin\alpha)+ \frac{1}{2} m_2v^2 + m_2g (h_2 - x)= m_1gh_1 + m_2gh_2$ $\Rightarrow \frac{1}{2} (m_1 + m_2) v^2 = (m_2 - m_1\sin\alpha) gx \Rightarrow v^2 = \frac{2(m_2 - m_1\sin\alpha)gx}{(m_1+m_2)}$.	¾
1.d	Derive the expression of v^2 w.r.t time , we get: $2va = \frac{2(m_2 - m_1\sin\alpha)g}{(m_1+m_2)} v \Rightarrow a = \frac{(m_2 - m_1\sin\alpha)g}{(m_1+m_2)}$.	1
A.2.a		1¼
2.b	The relation $\Sigma\vec{F}_{ext} = m_1\vec{a_1}$ applied on S_1 gives: $\vec{m_1g} + \vec{N_1} + \vec{T_1} = m_1\vec{a_1}$ ….. (1) Projecting (1) on the axis $\vec{ox}$ we get : $- m_1g\sin\alpha + T_1 = m_1a_1 \Rightarrow$ $T_1 = m_1g\sin\alpha + m_1a$ (with $a_1 = a_2 = a$). The relation $\Sigma\vec{F}_{ext} = m_2\vec{a_2}$ applied on S_2 gives : $m_2\vec{g} + \vec{T_2} = m_2\vec{a_2}$ …. (2) Projecting (2) on the vertically downward axis we get: $m_2g - T_2 = m_2a_2 \Rightarrow T_2 = m_2g - m_2a$.	2
2.c	The relation $T_1 = T_2$ gives: $m_1g\sin\alpha + m_1a = m_2g - m_2a$ $\Rightarrow a = (\frac{m_2 - m_1\sin\alpha}{m_1+m_2})g$.	½

Third exercise (6 ½ points)

Part of the Q	Answer	Mark
A.1.a	Conservation of nucleons number: 235 + 1 = 94 + A +3 then A = 139 Conservation of charge number: 92 = Z + 54 then Z = 38	**1**
A.1.b	$E = \Delta mc^2$ $= (234.9942+1.00866 - 93.8945 - 138.8892 - 3\times1.00866)\times931.5$ $\Rightarrow$ Energy = 179.947 MeV	**1**
A.1.c.i	We have 235+1 = 236 nucleons	**¼**
A.1.c.ii	$E_1 = \frac{179.947}{236} = 0.76$ MeV/nucleon	**¼**
A.2.a	$E_0 = \frac{179.947}{100} = 1.79947$ MeV; which is much greater than 0.025 eV	**½**
A.2.b	They should be slowed down,	**¼**
B.1	${}_1^1H$	**¼**
B.2	${}_1^2H + {}_1^3H \rightarrow {}_Z^AX + {}_0^1n$ 2+3 = A + 1 then A = 4 1+1 = Z then Z = 2 The helium nucleus ${}_2^4He$	**1**
B.3	$E' = \Delta mc^2 = (2.01355+3.0155 - 4.0015 - 1.00866)\times 931.5 = 17.596$ MeV	**1**
B.4	We have 2 + 3 = 5 nucleons $\Rightarrow E_1' = \frac{17.596}{5} = 3.5912$ MeV/nucleon	**½**
C	E_1' is greater than E_1 ; fusion is more efficient.	**½**

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الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	

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

First exercise: (7 points) **Horizontal elastic pendulum**

The aim of this exercise is to study the effect of the mass on the motion of a horizontal elastic pendulum.
This pendulum is formed of:
- an elastic spring (R), of negligible mass and of stiffness k = 400 N/m ,wound around a horizontal rod;
- a solid (B) considered as a particle of mass m = 100 g.

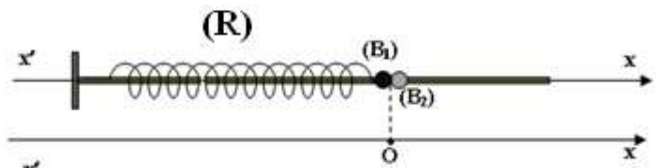


Fig. 1

The solid (B) is formed of two particles (B_1) and (B_2) stuck together and of respective masses m_1 = 25 g and m_2 = 75 g.
The solid (B) can slide, without friction, on the rod (Fig. 1). At equilibrium, (B) is at O, taken as an origin of abscissas of the axis x′x. (B) is displaced by a distance X_m, from O, in the positive direction, and then released without initial velocity at the instant $t_0 = 0$.
The horizontal plane through (B) is taken as a gravitational potential energy reference.
At the end of two complete oscillations, (B_2) is detached from (B_1) and the system [(R), (B_1)] continues its oscillations. Figure 2 represents the variation of the abscissa x of the moving solid as a function of time in the two intervals [0, 0.2 s] and [0.2s, 0.35 s]. Take $\pi^2 = 10$.

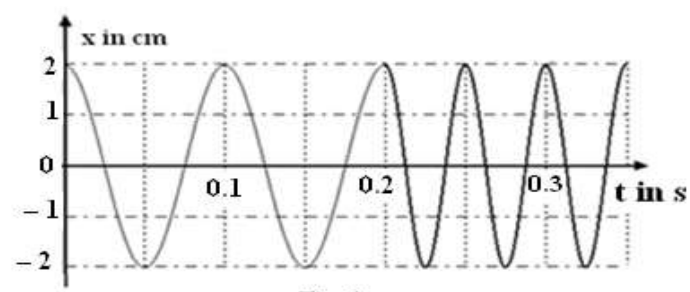


Fig. 2

A – Graphical study

Referring to figure 2, give in each of the intervals [0, 0.2 s] and [0.2s, 0. 35 s]:

1) the value of the amplitude of the motion;
2) the type of oscillations performed by the oscillator;
3) the value of the proper period of the oscillations.

B –Theoretical study of the oscillations of (B)

Consider the system [(R), (B), Earth].

1) Calculate, at $t_0 = 0$, the value of the mechanical energy of the system.
2) At an instant t, (B) has an abscissa x and a velocity $\vec{v}$ of algebraic value $v = \frac{dx}{dt}$.
Write, at an instant t, the expression of the mechanical energy of the system in terms of k, m, x and v.
3) **a)** Derive the second order differential equation in x that describes the motion of (B).
b) Deduce the expression of the proper period T of the oscillations.
c) Calculate the value of T, and then compare it to the result obtained in part **(A – 3).**
4) The time equation of motion of (B) is of the form: $x = X_m \sin(\frac{2\pi}{T} t + \varphi)$.
Determine the value of the constant φ.

C – Theoretical study of the oscillations of (B_1)

Consider the system [(R), (B_1), Earth].

1) Referring to figure 2, give the instant at which (B_2) is detached from (B_1).
2) The mechanical energy of the system [(R), (B_1), Earth] is equal to that of the system [(R), (B), Earth]. Justify.
3) When (B) passes through O, its speed is V and when (B_1) passes through O, its speed is V_1 . Show that $V_1 = 2$ V.

<u>Second exercise</u>: (7 points) **Study of discharging a capacitor**

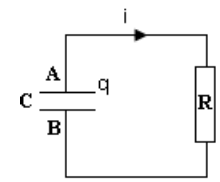


Fig.1

A capacitor of capacitance C is initially charged under a voltage E.
At $t_0 = 0$, we connect across the terminals of the capacitor a resistor of resistance R= 1 kΩ (Fig.1).
At an instant t, the armature A carries the charge q > 0 and the circuit carries a current i.

A – Theoretical study

1) Write the relation between i and q.
2) Show that the differential equation of the voltage $u_C = u_{AB}$ across the capacitor is $\frac{du_C}{dt} + \frac{1}{RC} u_C = 0$.
3) The solution of this differential equation is $u_C = D e^{\frac{-t}{\tau}}$.
   Determine the expressions of the constants D and τ in terms of E, R and C.
4) Show that, after a time t = τ, the voltage across the capacitor attains 37% of its maximum value E.

B – Determination of the capacitance C

In order to determine the value of C, we use a convenient apparatus, which traces, during the discharging of the capacitor, the curves representing $u_C = g(t)$ (Fig.2) and $\ell n(u_C) = f(t)$ (Fig.3)

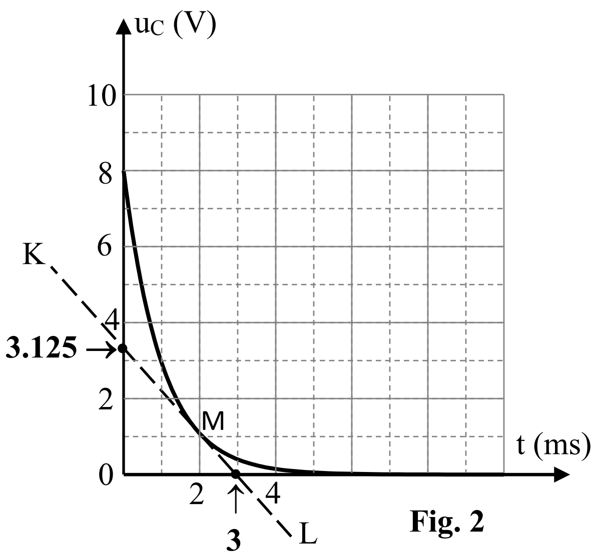


Fig. 2

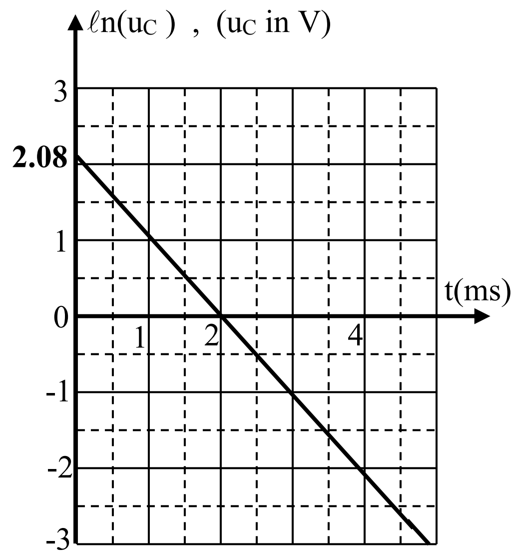


Fig.3

We proceed in the three following methods:

1) First method

Referring to the curve of figure 2:

a) give the value of E;
b) using the result of part (A – 4) determine the value of τ and deduce the value of C.

2) Second method

The figure 2 shows also the tangent KL to the curve at point M (2 ms, 1V).

a) Referring to this figure determine the slope of the tangent at point M.

b) Determine the value of C.

3) Third method:

a) Determine the expression of $\ell n\ (u_C)$ in terms of E, R, C and t.

b) Show that the shape of the curve in figure 3 is in agreement with the obtained expression of the function $\ell n\ (u_C) = f(t)$.

c) Referring to the curve of figure 3, determine again the values of E and C.

<u>Third exercise</u>: (6 points) **Iodine 131**

The aim of this exercise is to show evidence of some characteristics of iodine 131.

Iodine 131 ($^{131}_{53}I$) is radioactive and is a β^- emitter. Its radioactive period (half-life) is 8 days.

Given: Mass of an electron: $m_e = 5.5\times10^{-4}$ u; 1 MeV = 1.6×10^{-13} J; 1 u = 931.5 MeV/c^2.

Element	Iodine ($^{131}_{53}I$)	Cesium($^{137}_{55}Cs$)	Xenon($^{131}_{54}Xe$)
Mass of nucleus	130.8770 u	136.8773 u	130.8754 u

A – Disintegration of iodine 131

1) Write down the equation of the disintegration of iodine 131 and identify the daughter nucleus.

2) The disintegration of iodine 131 nucleus, is often, accompanied with the emission of γ rays. Due to what is this emission?

3) Calculate the radioactive constant λ of iodine 131 in day^{-1} and in s^{-1} .

4) Show that the energy liberated by the disintegration of one nucleus of iodine 131 is $E_{lib.} = 1.56\times10^{-13}$ J.

B – Application in medicine

During a medical examination of a thyroid gland of a patient, we inject this gland with a solution of iodine 131. The thyroid of this patient captures from this solution a number $N = 10^{11}$ of iodine nuclei.

1) Calculate, in Bq, the activity A corresponding to these N nuclei knowing that $A = \lambda N$.

2) Calculate, in J, the energy liberated by the disintegration of these N nuclei.

3) Deduce, in J/kg, the value of the dose absorbed by the thyroid gland knowing that its mass is 25 g.

C – Contamination

On the 26th of April 1986, an accident took place in the nuclear power plant of Chernobyl that provoked an explosion in one of the reactors. One of the many radioactive elements that were ejected to the atmosphere is the iodine 131. This element spread on the ground, absorbed by cows and contaminated their milk and then captured by the thyroid gland of consumers.

Every morning, a person drank a certain quantity of milk containing $N_0 = 2.6\times10^{16}$ nuclei of iodine 131.

We suppose that all these nuclei were captured by the thyroid of that person, and that the person drank the first quantity at the instant $t_0 = 0$.

1) Determine , in terms of N_0 and λ (expressed in day^{-1}), the number of iodine 131 nuclei that remained in the thyroid, at the instant:

- **a)** $t_1 = 1$ day, (just after drinking the 2nd quantity of milk);
- **b)** $t_2 = 2$ days, (just after drinking the 3rd quantity of milk).

2) Deduce, at the instant $t_3 = 3$ days just after drinking the 4th quantity of milk that the number N_3 of the iodine 131 nuclei that remained in the thyroid is: $N_3 = N_0\ (1 + e^{-\lambda} + e^{-2\lambda} + e^{-3\lambda})$ where λ is expressed in day^{-1}.

3) Serious troubles in the thyroid gland will take place if the activity of the iodine 131 exceeds 75×10^9 Bq. Show that at the instant t_3, the person was in danger.

مشروع معيار التصحيح

First exercise: Horizontal elastic pendulum		7 points
Part of the Q.	Answer	Mark
A.1	X_m of B is 2cm and X_m of B_1 is 2cm also	½
A.2	The oscillations in each part are free un-damped oscillations.	½
A.3	The periods are: $T_B = 0.1$ s and $T_{B1} = 0.05$ s.	¾
B.1	M.E is conserved since the amplitude of the oscillations are constant $M.E = K.E + P.E_e + P.E_g = \frac{1}{2} m v^2 + \frac{1}{2} kx^2 + 0$, for $x = X_m$, $v = 0$ thus $M.E = P.E_{max} = \frac{1}{2} kX^2_m$. $M.E = 200 \times (0.02)^2 = 0.08$ J.	¾
B.2	$M\ E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$	¼
B.3.a	$M.E = \frac{1}{2} m v^2 + \frac{1}{2} kx^2$. Being constant , its derivative is zero thus: $0 = mvv' + kxx'$ $v = x' \neq 0$ and $v' = x''$ we get $x'' + (\frac{k}{m})x = 0$	1
B.3.b	The differential equation is of the form: $x'' + \omega^2 x = 0$ $\Rightarrow \omega^2 = \frac{k}{m} \Rightarrow T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$	½
B.3.c	$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}} = \frac{2\pi}{20\pi} = 0.1$ s ; which is in agreement with the result obtained in part A.3	¼ ¼
B.4	The time equation is $x = X_m \sin(\frac{2\pi}{T}t + \phi)$, at $t_0 = 0$, $x = X_m$	½

	$X_m = X_m \sin(\phi) \Rightarrow \sin(\phi) = 1 \Rightarrow \phi = \frac{\pi}{2}$ rd;	
C.1	B_2 detached at t = 0.2 s	¼
C.2	M.E is the same in the two intervals since the M.E = [$P.E_{el}$] max = ½ k X_m^2 , same K and same X_m	½
C.3	At O, The M.E = kinetic energy becuase x = 0, the elastic potential energy is zero ($P.E_{el}$ = 0). For B : 0.08 = ½ mV^2 and for B_1 : 0.08 = ½ $m_1 V_1^2$, m_1 = 25 g and m = 100 g = $4m_1 \Rightarrow 4m_1 v^2 = m_1 V_1^2 \Rightarrow$ $V_1^2 = 4 v^2$ and $V_1 = 2v$.	1

Second exercise: Study of discharging a capacitor		**7 points**
Part of the Q	**Answer**	**Mark**
A.1	$i = -\frac{dq}{dt}$	¼
A.2	$u_C = Ri = -R\frac{dq}{dt} = -RC\frac{du_C}{dt}$; $u_C + RC\frac{du_C}{dt} = 0$	½
A.3	$\frac{du_C}{dt} = -\frac{D}{\tau}e^{\frac{-t}{\tau}} \Rightarrow -\frac{D}{\tau}e^{\frac{-t}{\tau}} + \frac{1}{RC} \times D e^{\frac{-t}{\tau}} = 0 \Rightarrow \tau = RC$. For t = 0, u_C = E=D.	1
A.4	$u_C = E e^{\frac{-t}{\tau}}$, for $t = \tau \Rightarrow u_C = E e^{-1} = 0.37$ E	¾
B.1.a	E = 8 V	¼
B.1.b	u_C = 0.37 E =0.37×8 = 2.96 V ≈ 3V. Graphically, we find for u_C = 3V, t = τ =1ms = 10^{-3}s. τ =RC=10^3C$\Rightarrow$ C = 10^{-6}F.	1

B.2.a	slope = $\frac{du_C}{dt} = -\frac{3.125}{0.003}$ = –1041.6 V/s	½
B.2.b	The differential equation is: $\frac{du_C}{dt} + \frac{1}{RC}u_C = 0 \Rightarrow \frac{du_C}{dt} = -\frac{1}{RC}u_C$ $-\frac{1}{RC}u_C = -\frac{1}{10^3 C} \times 1 \Rightarrow 1041.6 = \frac{1}{10^3 C} \Rightarrow$ C= 0.96×10^{-6}F.	¾
B.3.a	ln (u_C) = ln$(E e^{\frac{-t}{\tau}}) \Rightarrow$ ln (u_C) = lnE $- \frac{t}{RC}$.	¾
B.3.b	ln (u_C) = f(t) is a function of time: the shape of the curve is a straight line decreasing and not passing through the origin.	¼
B.3.c	For t =0, we have: ln (u_C) = 2.08 = lnE $\Rightarrow$ E = 8 V. And ln (u_C) = 0 , for t = 2ms $\Rightarrow$ lnE = ln8 thus E = 8 V Now ln8 = 2.08 = $\frac{2 \times 10^{-3}}{10^3 \times C} \Rightarrow$ C = 0.96×10^{-6}F.	1

Third exercise: **Iodine 131**		**6 points**
Part of the Q.	**Answer**	**Mark**
A.1	${}^{131}_{53}I \rightarrow {}^{A}_{Z}X + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$	1

	conservation of mass number : A = 131 conservation of charge number : 53 = Z - 1⇒ Z = 54 Daughter nucleus is Xenon $^{131}_{54}Xe$	
A.2	The daughter nucleus $^{131}_{54}Xe$ is in excited state and when it drops to the ground state (lower state) emits the γ ray (photon)	¼
A.3	$\lambda = \frac{\ln 2}{T} = \frac{0.693}{8}$ = 0.087 days^{-1} and $\lambda = \frac{0.087}{24 \times 3600}$ = 10^{-6} s^{-1}.	¾
A.4	$\Delta m = m_{before} - m_{after}$ = 130.8770 – 130.8754 – 5.5 $\times 10^{-4}$ = 1.05×10^{-3} u $\Delta m = 1.05\times10^{-3} \times 931.5 = 0.978$ MeV $\times 1.6\times 10^{-13} = 1.56\times 10^{-13}$ J	1
B.1	A= λ N=$10^{-6} \times 10^{11}$ =10^5 Bq.	¼
B.2	The liberated energy is : E= $10^{11}\times1.56\times 10^{-13}=1.56\times10^{-2}$ J	¼
B.3	The absorbed dose is: D=$\frac{E}{m} = \frac{1.56\times10^{-2}}{25\times10^{-3}} =$0.624 J/kg	½
C.1.a	After the duration t_1=1 day, according to the law of radioactive decay the number of remaining nuclei is $N_1=N_0 e^{-\lambda t} = N_0 e^{-\lambda}$ (λ in day^{-1}) An additional number N_0 is taken when drinks the second quantity next morning. Thus the number of non-decay nuclei is then: $N_1=N_0+ N_0 e^{-\lambda} = N_0 (1+e^{-\lambda})$	¾
C.1.b	On the 2nd day, an additional N_0 from the third quantity and the number remaining from the previous milk is $N_1 e^{-\lambda}$: $N_2= N_1 e^{-\lambda} + N_0= N_0(1+e^{-\lambda}) e^{-\lambda} + N_0= N_0(1+e^{-\lambda}+e^{-2\lambda})$	¼
C.2	On the 3rd day, an additional N_0 from the fourth quantity and the number remaining from the previous milk is $N_2 e^{-\lambda}$. $N_3= N_2 e^{-\lambda} + N_0= N_0(1+e^{-\lambda}+e^{-2\lambda}) e^{-\lambda} + N_0= N_0(1+e^{-\lambda}+e^{-2\lambda}+e^{-3\lambda})$	¼
C.3	À t=3 days, the number N_3 of nuclei is : $N_2= N_0 (1+e^{-0.087}+e^{-2\times0.087}+e^{-3\times0.087})$ = 9.17×10^{16} nuclei. The corresponding activity becomes : $A_3 = \lambda N_3 = 10^{-6}\times 9.17\times10^{16}$=91.7 GBq > 75G Bq At the instant t_3 , the person is thus in danger.	¾

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

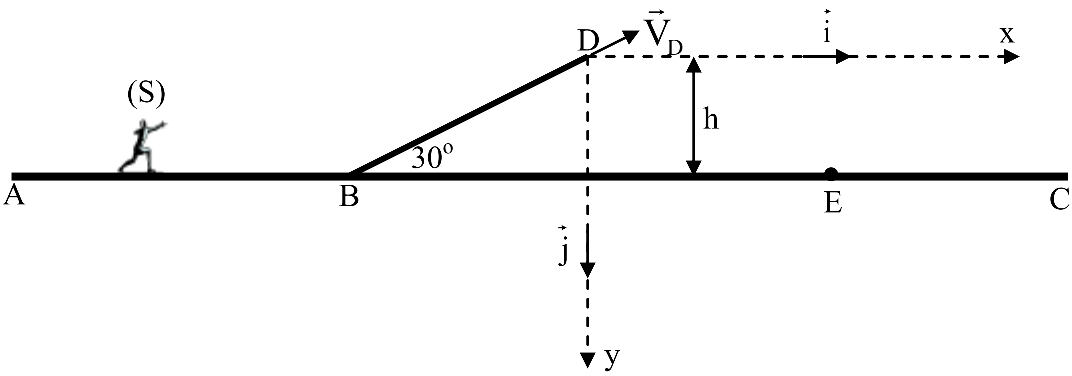
First exercise: (7 points)

Study of the motion of a skier

A skier (S), of mass m = 80 kg, is pulled by a boat using a rope parallel to the surface of water. He starts from point A at the instant $t_0 = 0$ without initial velocity.

The skier passes point B at the instant t = 60 s with a speed $V_B = 6$ m/s, then he releases the rope. He continues his motion along a board BD inclined by an angle of 30° with respect to the horizontal surface of water. Suppose that during the passage from AB to BD the speed at point B does not change.

The skier arrives point D, situated at an altitude h = 1.6 m from the water surface, with a velocity $\vec{V}_D$, then he leaves the board at point D to hit the water surface at point E (see figure below).



Given:

- the skier is considered as a particle;
- on the path AB, the force of traction $\vec{F}$ exerted by the rope on the skier has a constant magnitude F and the whole forces of friction are equivalent to a single force $\vec{f}$ opposite to the displacement, of magnitude f = 100 N;
- friction is negligible along the path BDE;
- after leaving point D the motion of the skier takes place in the vertical plane Dxy containing $\vec{V}_D$;
- the horizontal plane passing through AB is the reference level of the gravitational potential energy;
- g = 10 m/s^2.

A – Motion of the skier between A and B

1) What are the external forces acting on (S) along the path AB? Draw, not to scale, a diagram of these forces.

2) Applying Newton's second law $\frac{d\vec{P}}{dt} = \Sigma\vec{F}_{ext}$ on the skier, between the points A and B, express the acceleration a of the motion of the skier in terms of F, f and m.

3) Determine the expression of the speed V of the skier in terms of F , f , m and the time t.

4) Deduce F.

B – Motion of the skier on the board BD

1) Why can we apply the principle of conservation of the mechanical of energy of system [(S), Earth] on the path BD?
2) Deduce that $V_D = 2$ m/s.

C – Motion of the skier between D and E

The skier leaves the board at point D, at an instant t_0, taken as a new origin of time.

1) Apply Newton's second law on the skier to show that, at an instant t, the vertical component P_y of the linear momentum of the skier is of the form: $P_y = 800\,t - 80$ (In SI unit).
2) Deduce the parametric equation y(t) of the motion of the skier in the frame of reference Dxy.
3) Determine the duration taken by the skier to pass from D to E.

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

Electromagnetic induction and self-induction

A – Electromagnetic induction

A coil, of horizontal axis, is made up of N = 500 circular turns each of surface area S = 10 cm^2. The normal $\vec{n}$ to the planes of the turns of the coil is directed as indicated in figure 1.

The coil rotates at a constant angular velocity ω about a vertical axis (Δ) in a horizontal, constant and uniform magnetic field $\vec{B}$. The terminals A and C of the coil are connected to the input Y and the ground M of an oscilloscope respectively. Let θ be the angle between $\vec{n}$ and $\vec{B}$ at an instant t.

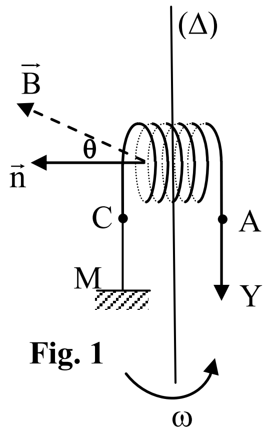
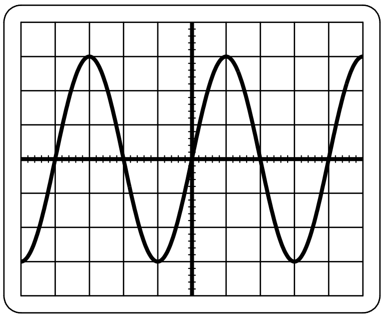


Fig. 1

1) Knowing that θ = 0 at the instant $t_0 = 0$, show that θ = ωt.
2) Deduce that the expression of the magnetic flux crossing the coil is given by: $\phi = NBS\cos(\omega t)$.
3) Justify, qualitatively, the existence of an induced e.m.f "e" during the rotation of the coil.
4) **a)** Determine, in terms of N, S, B, ω and t, the expression of the induced e.m.f "e".
   b) The coil does not carry a current. Why?
   c) Deduce the expression of the voltage u_{AC} in terms of N, S, B, ω and t, supposing that the coil is oriented positively from A to C.
5) The waveform of figure 2 represents the variation of the voltage u_{AC} as a function of time. Using this waveform, determine:
   a) the angular velocity ω of the coil;
   b) the maximum value of the voltage u_{AC};
   c) the value B of the magnetic field $\vec{B}$.



$S_h = 10$ ms/div **Fig.2**
$S_V = 1$V/div

B – Self-induction

The coil is of negligible resistance and of inductance L. It is connected in series with a resistor of resistance R = 1 kΩ and a generator G (fig. 3). The circuit of figure 3 thus carries a triangular current i. The positive orientation of the circuit is as that of the current.

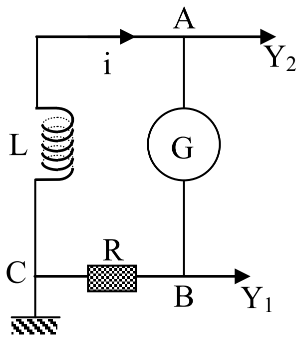
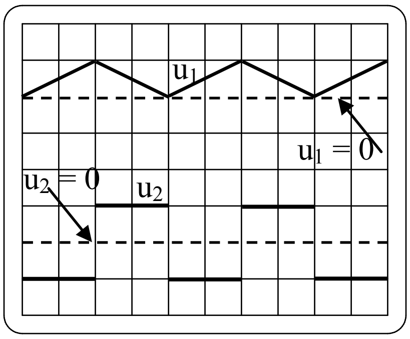


Fig. 3

With the aid of the oscilloscope, we visualize the variations of the voltages $u_1 = u_{BC}$ across the resistor and $u_2 = u_{AC}$ across the coil (fig. 4).

1) Show that $u_2 = -\frac{L}{R}\frac{du_1}{dt}$.
2) The shape of the waveform obtained on Y_2 is square. Justify this shape.
3) Determine the value of L.



S_h = 5 ms/div ; **Fig. 4**
S_{v1} = 1 V/div; S_{v2} = 10 mV/div

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

Sodium vapor lamp

A sodium vapor lamp emits mainly a yellow light called doublet of wavelengths 589.0 nm and 589.6 nm. Other wavelengths are also emitted, as those: λ_1 = 330.3 nm, λ_2 = 568.8 nm, λ_3 = 615.4 nm, λ_4 = 819.5 nm and λ_5 = 1138.2 nm.
Figure 1 below shows only the yellow doublet of the emission spectrum of the sodium atom.

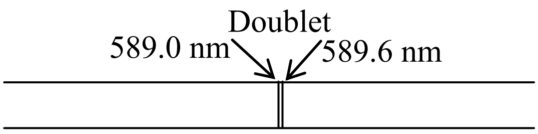


Fig. 1

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

A – Spectrum analysis

1) To what range: visible, infrared or ultraviolet, does each of the radiations of the wavelengths λ_1 , λ_2 , λ_3 , λ_4 and λ_5 belong?
2) Is the sodium vapor lamp a monochromatic or a polychromatic source of light? Justify your answer.
3) Consider the yellow radiation of wavelength 589.0 nm. Show that the value of the energy of a photon corresponding to this radiation is approximately 2.11 eV.

B – Energetic analysis of the diagram

Figure 2 shows a simplified diagram of the energy levels of a sodium atom.

1) **a)** One of these energy levels represents the ground state. Specify which one.
   b) What do we call each of the other shown levels?
2) **a)** Define the emission spectrum.
   b) Use the diagram of figure 2 to justify the discontinuity of the emission spectrum.
3) The emission of the yellow radiation of wavelength 589.0 nm is due to the transition of the sodium atom from an excited level E_n to the ground state. Determine E_n.
4) In fact, the energy level E_n is double. This double is constituted of two energy levels E_n and E'_n that are very close to each other. Compare, with justification, E_n and E'_n.

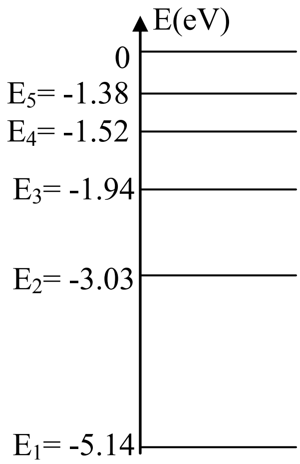
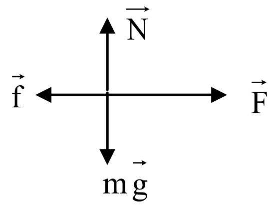


Fig. 2

5) The sodium atom , being in an excited state E_x, receives a photon carrying an energy 1.51 eV and passes to another excited state E_y; E_x and E_y exist on the diagram of figure 2.
   a) Determine the two levels E_x and E_y.
   b) Is the spectral line associated with the transition x→y an emission or absorption line? Justify your answer.

الدورة الإستثنائية للعام **2012**	**امتحانات الشهادة الثانوية العامة** **الفرع : علوم الحياة**	**وزارة التربية والتعليم العالي** **المديرية العامة للتربية** **دائرة الامتحانات**
الاسم: **الرقم:**	مسابقة في مادة الفيزياء المدة ساعتان	**مشروع معيار التصحيح**

First exercise (7 points)

Part of the Q	Answer	Mark
A.1	I The forces acting on (S) are: the weight $m\vec{g}$, the normal reaction of the surface of water $\vec{N}$, $\vec{F}$ and $\vec{f}$. 	½
A.2	$\frac{d\vec{P}}{dt} = \Sigma\overrightarrow{F_{ext}} = \overrightarrow{mg} + \vec{N} + \vec{F} + \vec{f}$ project along the direction of motion $\Rightarrow$ $\frac{dP}{dt} = F - f \Rightarrow$ ma= F – f $\Rightarrow a = \frac{F-f}{m}$	1
A.3	V = primitive of a = at $+V_o$ ($V_o = 0$) then $V = (\frac{F-f}{m})$ t.	¾
A.4	$V = V_B = 6$ m/s for t = 60 s $\Rightarrow 6 = (\frac{F-100}{80})60 \Rightarrow F = 108$ N	¾
B.1	Since friction is negligible between B and D	¼
B.2	$ME_B = ME_D \Rightarrow$ ½ $m(V_B)^2 + 0 =$ ½ $m(V_D)^2 + mgh$ $\Rightarrow$ ½(80)(36) = ½(80)$(V_D)^2 + 80\times10\times1.6 \Rightarrow V_D = 2$ m/s.	1
C.1	$\frac{d\vec{P}}{dt} = \Sigma\overrightarrow{F_{ext}} = mg\vec{j} \Rightarrow \frac{dP_y}{dt} = mg \Rightarrow P_y = mgt + P_{0y}$ $P_{0y} = mV_{0y} = m(-V_D \sin30^o) = -80\times2\times\frac{1}{2} = -80$ $\Rightarrow P_y = 800t - 80$	1
C.2	$V_y = \frac{P_y}{m} = 10t - 1 \Rightarrow y = 5t^2 - t + y_o = 5t^2 - t$ (y_o =0).	¾
C.3	$1.6 = 5t^2 - t \Rightarrow 5t^2 - t + 1.6 = 0 \Rightarrow \Delta = 1 + 32 = 33$ $t = \frac{1\pm\sqrt{33}}{10} \Rightarrow t = \frac{1+\sqrt{33}}{10} = 0.67$ s.	1

Second exercise (7 points)

Part of the Q	Answer	Mark
A.1	The angular velocity is constant, therefore: $\theta = \omega \cdot t + \theta_0$ with $\theta_0 = 0$	½
A.2	The magnetic flux through the coil is: $\phi = N\vec{B}\cdot S\vec{n} = NBS\cos(\theta) = NBS\cos(\omega t)$	¼
A.3	During the rotation of the coil, θ varies ⇒ magnetic flux varies , therefore e exists. Or ϕ is a function of time, then ϕ varies so e exists.	½
A.4.a	$e = -\dfrac{d\varphi}{dt} = -NBS[-\omega\sin(\omega t)] \Rightarrow e = NBS\,\omega\sin(\omega t)$.	½
A.4.b	Since the circuit is not closed (the resistance of the oscilloscope is too large or the circuit is open) .	¼
A.4.c	$u_{AC} = ri - e = -NBS\,\omega\sin(\omega t)$.	½
A.5.a	The period T = 40 ms $\Rightarrow \omega = \dfrac{2\pi}{T} = 157$ rd/s.	¾
A.5.b	$u_{AC}(max) = 3$ div × 1V = 3 V.	¼
A.5.c	$u_{AC}(max) = NBS\,\omega$ $\Rightarrow B = \dfrac{u_{AC}(max)}{NS\omega} = \dfrac{3}{500\times10\times10^{-4}\times157} = 0.038T$.	¾
B.1	$u_2 = u_{AC} = e - ri = e = -L\dfrac{di}{dt}$ and $u_1 = R\,i \Rightarrow i = \dfrac{u_1}{R} \Rightarrow \dfrac{di}{dt} = \dfrac{1}{R}\dfrac{du_1}{dt}$ Thus $u_2 = -\dfrac{L}{R}\dfrac{du_1}{dt}$.	1
B.2	In the first half period, i is a linear function of time (i = at + b) ⇒ $u_1 = Ri = Rat + Rb$ $u_2 = -\dfrac{L}{R}\dfrac{du_1}{dt} = -\dfrac{L}{R}Ra = -La =$ constant. In the second half period, same explanation gives $u_1 = La$, Therefore the form of u_2 is a square.	¾
B.3	In the first half period : $\dfrac{du_1}{dt} = \dfrac{1\times1}{2\times5\times10^{-3}} = 100$ V/s and $u_2 = -10\times10^{-3}$ V $= -\dfrac{L}{1000}\times100 \Rightarrow L = 0.1$ H or 100 mH.	1

Third exercise (6 points)

Part of the Q	Answer	Mark
A.1	λ_1 : U.V ; λ_2 and λ_3: visible ; λ_4 and λ_5 : I.R.	¾
A.2	It is polychromatic since it is formed of many wavelengths (radiations).	½
A.3	$E = h\nu = h\frac{c}{\lambda} = 3.37\times10^{-19}$ J = 2.11 eV	½
B.1.a	The energy level – 5.14 eV corresponds to a ground state, since it is the lowest energy level.	½
B.1.b	E_2, E_3,E_4 and E_5 are excited state. The energy level 0, corresponds to the ionization state	½
B.2.a	The emission spectrum is the set of spectral lines emitted by an atom.	¼
B.2.b	To each electronic transition between two energy levels corresponds an emission line and since the energy levels diagram of the sodium atom are discontinious, then the spectral lines must be discontinuous.	½
B.3	$E_n - E_1 = 2.11$ eV ; $E_n = 2.11 + E_1 = 2.11 + (-5.14) = -3.03$ eV = E_2.	½
B.4	$\left.\begin{array}{l} E_n - (-5.14) = \frac{hc}{\lambda} \\ E'_n - (-5.14) = \frac{hc}{\lambda'} \end{array}\right\}$ $\boxed{\lambda' > \lambda \Rightarrow E'_n < E_n}$ **<u>Or</u>** : the variation of the energy ΔE is inversely proportional to the wavelength of the emitted radiation ; $\lambda' > \lambda$ and $\Delta E' < \Delta E \Rightarrow E'_n < E_n$	1
B.5.a	$E_y - E_x = 1.51$ eV corresponds to $E_4 - E_2 = 1.51$ eV. Thus $E_x \rightarrow E_2$ and $E_y \rightarrow E_4$	½
B.5.b	The associated spectral line is an absorption line because the atom passes from one level to a higher energy level, so it absorbs energy.	½

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الجمعة 28 حزيران 2013	مسابقة في مادة الفيزياء المدة ساعتان	الاسم: الرقم:

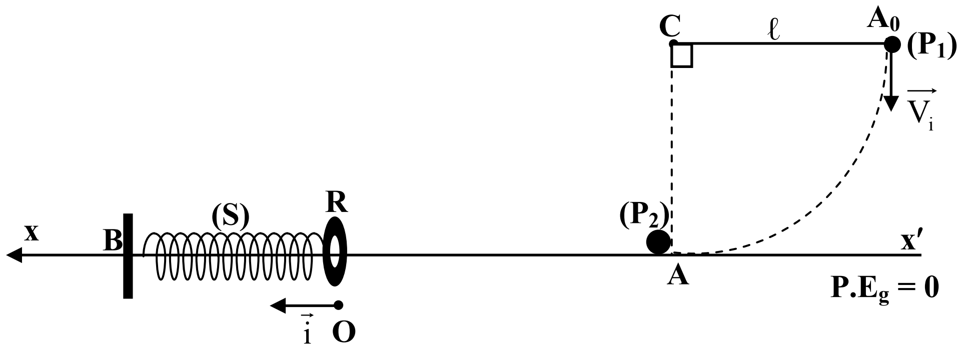
This exam is formed of three obligatory exercises in 3 pages numbered from 1 to 3
The use of non-programmable calculator is recommended

First exercise: (7 points)

Collisions and mechanical oscillator

A – Collision

A pendulum is formed of a massless and inextensible string of length $\ell = 1.8$ m, having one of its ends C fixed to a support while the other end carries a particle (P_1) of mass $m_1 = 200$ g .
The pendulum is stretched horizontally. The particle (P_1) at A_0 is then launched vertically downward with a velocity $\vec{V}_i$ of magnitude $V_i = 8$ m/s.
At the lowest position A, (P_1) enters in a head-on perfectly elastic collision with another particle (P_2) of mass $m_2 = 300$ g initially at rest. Neglect all frictional forces.



Take:

- the horizontal plane passing through A as a gravitational potential energy reference;
- $g = 10$ m/s^2.

1) **a)** Calculate the mechanical energy of the system [pendulum, Earth] at the instant of launching (P_1) at A_0.

b) Determine the magnitude V_1 of the velocity $\vec{V_1}$ of (P_1) just before colliding with (P_2).

2) **a)** Name the physical quantities that are conserved during this collision.

b) Show that the magnitude V_2' of the velocity $\vec{V}_2'$ of (P_2), just after collision, is 8 m/s.

B – Mechanical oscillator

A horizontal spring (S), of negligible mass and of stiffness K = 120 N/m, is connected at one of its ends B to a fixed support while the other end is attached to a ring R.
(P_2) moves on the horizontal path AB until it hits the ring R at point O; (P_2) sticks to R forming a solid (P) , considered as a particle, of mass m = 1.2 kg. Thus (P) and the spring (S) form a horizontal mechanical oscillator of center of inertia G; G moves without friction on a horizontal axis x′Ox along AB. Just after collision and at the initial instant $t_0 = 0$, G coincides with O, the equilibrium position of (P), and has a velocity $\vec{V}_0 = V_0\vec{i}$ with $V_0 = 2$ m/s.

At an instant t, the abscissa of G is x and the algebraic value of its velocity is $v = \frac{dx}{dt}$.

1) Write down the expression of the mechanical energy of the system (oscillator, Earth) at an instant t, in terms of K, m, x and v.

2) Derive the differential equation in x that describes the motion of G and deduce the nature of its motion.

3) Knowing that the solution of this differential equation is $x = X_m \cos(\sqrt{\frac{K}{m}}\,t + \varphi)$, determine the values of the constants X_m and φ.

Second exercise: (7 points)

Determination of the characteristics of a coil and a capacitor

The aim of this exercise is to determine the characteristics of a capacitor and a coil.
In order to determine these characteristics, we connect in series a capacitor of capacitance C, a coil of inductance L and of resistance r , a resistor of resistance $R = 20\ \Omega$ and a low frequency generator (LFG) delivering an alternating sinusoidal voltage u of constant maximum value U_m and of adjustable frequency f.
The circuit thus formed, carries an alternating sinusoidal current i (Fig. 1).

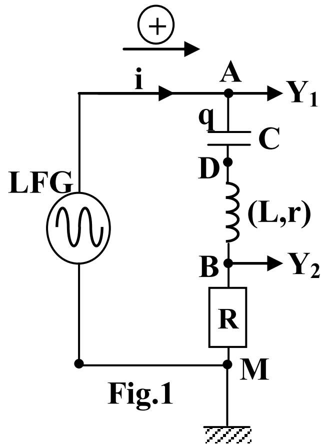


Fig.1

An oscilloscope is connected to display the voltage $u = u_{AM}$ across the terminals of the (LFG) on channel (Y_1) and the voltage u_{BM} across the terminals of the resistor (R) on channel (Y_2).
The settings of the oscilloscope are:
horizontal sensitivity: $S_h = 2$ ms/div;
vertical sensitivity: - On (Y_1) : $S_{V1}= 2$ V/div ;
- On (Y_2) : $S_{V2}= 0.25$ V/div.

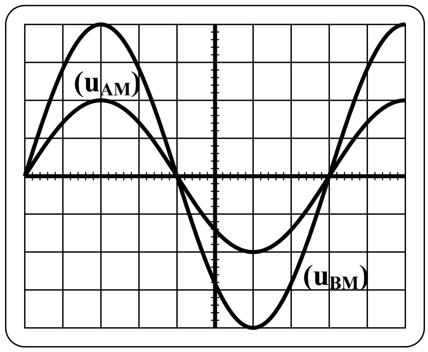


Fig.2

A – For a given value f_o of the frequency f we observe on the screen of the oscilloscope the waveforms represented by figure 2.

1) Determine f_o and the proper angular frequency ω_o.
2) Determine the maximum value U_m of u and the maximum current I_m of i.
3) **a)** The waveforms show that a physical phenomenon takes place in the circuit. Name this phenomenon. Justify.
b) Deduce the relation between L and C.
4) The circuit between A and M is equivalent to a resistor of resistance $R_t = R + r$. Determine R_t and deduce r.

B – The coil in the circuit of figure 1 is replaced by a resistor r_1 of resistance $r_1 = 60\Omega$ (figure 3).
The voltage across the terminals of the generator is $u = u_{AM} = U_m\cos\omega_o t$.
On the screen of the oscilloscope, we observe the waveforms represented by figure 4. The settings of the oscilloscope are not changed.

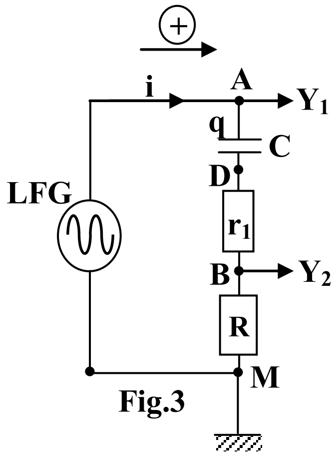


Fig.3

1) Using the waveforms of figure 4:
a) tell why the voltage u_{AM} lags behind u_{BM};
b) calculate the phase difference φ between u_{AM} and u_{BM} ;
c) determine the expressions of u_{BM} and of u_{AM} as a function of time t.
2) Write down the expression of i as a function of time t.
3) The voltage across the terminal of the capacitor is:

$$u_C = u_{AD} = \frac{8.9\times10^{-5}}{C}\sin(125\pi t + \frac{\pi}{4})\ ;\ [u \text{ in V and t in s}].$$

By applying the law of addition of voltages and giving t a particular value, determine the value of C.

C – Use the relation found in part [A-3 (b)] , calculate L.

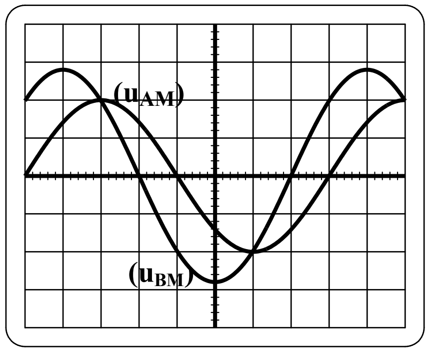


Fig.4

Third exercise: (6 points)

Dating by Carbon 14

The radioactive carbon isotope $^{14}_{6}C$ is a β^- emitter. In the atmosphere, $^{14}_{6}C$ exists with the carbon 12 in a constant ratio.

When an organism is alive it absorbs carbon dioxide that comes indifferently from carbon 12 and carbon 14. Just after the death of an organism, this absorption stops and carbon 14, that it has, disintegrate with a half life T = 5700 years.

In living organisms, the ratio of the number of carbon 14 atoms to that of the number of carbon 12 atoms is: $r_0 = \dfrac{\text{initial number of carbon 14 atoms}}{\text{number of carbon 12 atoms}} = \dfrac{N_o(^{14}C)}{N'(^{12}C)} = 10^{-12}$.

After the death of an organism by a time t, the ratio of the number of carbon 14 atoms to that of the number of carbon 12 atoms becomes: $r = \dfrac{\text{remaining number of carbon 14 atoms}}{\text{number of carbon 12 atoms}} = \dfrac{N(^{14}C)}{N'(^{12}C)}$.

1) The disintegration of $^{14}_{6}C$ is given by: $^{14}_{6}C \rightarrow {}^{A}_{Z}N + \beta^- + {}^{0}_{0}\bar{\upsilon}$.
Calculate Z and A , specifying the laws used.

2) Calculate, in year^{-1}, the radioactive constant λ of carbon 14.

3) Using, the law of radioactive decay of carbon 14, $N(^{14}C) = N_o(^{14}C) \times e^{-\lambda t}$.
Show that $r = r_0 e^{-\lambda t}$.

4) Measurements of $\dfrac{r}{r_0}$, for specimens a, b and c, are given in the following table:

ratio	specimen a	specimen b	specimen c
$\dfrac{r}{r_0}$	0.914	0.843	0.984

a) Specimen b is the oldest. Why?
b) Determine the age of specimen b.

5) a) Calculate the ratio $\dfrac{r}{r_0}$ for $t_0 = 0$, $t_1 = 2T$, $t_2 = 4T$ and $t_3 = 6T$.

b) Trace then the curve $\dfrac{r}{r_0} = f(t)$ by taking the following scales:

- On the abscissa axis: 1 cm $\rightarrow$ 2T
- On the ordinate axis: 1 cm $\rightarrow \dfrac{r}{r_0} = 0.2$

c) To determine the date of death of a living organism, it is just enough to measure $\dfrac{r}{r_0}$.
Explain why we cannot use the traced curve to determine the date of the death of an organism that died several millions years ago.

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

Solutions

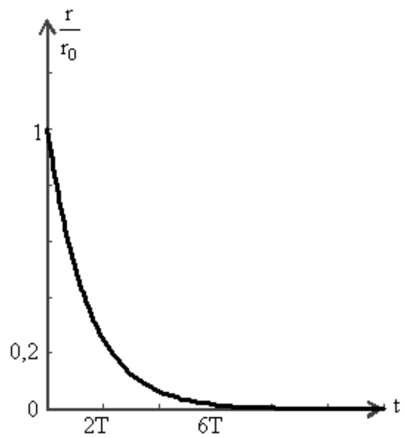
First exercise (7 points)

Part of the Q	Answer	Mark
A-1-a	$ME_i = KE_i + PEg_i = ½m_1 V_i^2 + m_1 g\ell = 0.5×0.2×64 + 0.2×10×1.8 = 10$ J	0.75
A-1-b	Since there is no friction then ME is conserved so $ME_i = 10 = ME_A = \frac{1}{2} m_1 V_1^2 + 0$ $\Rightarrow 10 = 0.1V_1^2 + 0 \Rightarrow V_1 = 10$ m/s.	0.75
A-2.a	The linear momentum and the kinetic energy.	0.50
A-2.b	Conservation of linear momentum: $m_1 \overrightarrow{V_1} + 0 = m_1 \overrightarrow{V'_1} + m_2 \overrightarrow{V'_2}$ but no deviation (head-on) $\Rightarrow m_1V_1 + 0 = m_1V'_1 + m_2V'_2 \Rightarrow m_1 (V_1 - V'_1) = m_2V'_2$ …. (1) collision is elastic: $½ m_1V_1^2 = ½ m_1 (V'_1)^2 + ½ m_2(V'_2)^2$ $\Rightarrow m_1[V_1^2 - (V'_1)^2] = m_2 (V'_2)^2$ (2) Divide (2) by (1) we get: $V_1 + V'_1 = V'_2$ (3) Equations (1) and (3) give: $V'_2 = 8$ m/s.	1.5
B-1	$M.E = ½ kx^2 + ½ mV^2$.	0.5
B-2	M.E = constant $\Rightarrow \frac{dM.E}{dt} = 0$ $\Rightarrow kxx' + mVV' = 0$; $V = x' \neq 0$ and $V' = x''$ $\Rightarrow x'' + (\frac{K}{m})x = 0$. This differential equation has the form of $x'' + \omega_0^2 x = 0$; The motion is simple harmonic.	1
B-3	$ME_{x=0} = ME_{x=xm} \Rightarrow \frac{1}{2} mV_o^2 + \frac{1}{2} Kx_o^2 = \frac{1}{2} KX_m^2$ $\frac{1}{2} ×1.2×2^2 + 0 = \frac{1}{2} × 120 × X_m^2 \Rightarrow X_m = 0.2$ m = 20 cm. $x = X_m\cos(\sqrt{\frac{K}{m}}\, t + \varphi)$ at t = 0 s, $x = 0 \Rightarrow 0 = X_m \cos\varphi \Rightarrow \cos\varphi = 0 \Rightarrow \varphi = \pm \frac{\pi}{2}$ but at t = 0 we have $v = V_o = - X_m\sin \varphi > 0 \Rightarrow \varphi = -\frac{\pi}{2}$ rd	1 1

Second exercise (7 points)

Part of the Q	Answer	Mark
A-1	$T_o = 8 \times 2 = 16$ ms $\Rightarrow f_o = \frac{1}{T_o} = 62.5$ Hz and $\omega_o = 2\pi f_o = 125\pi$ rd/s.	0.5 ; 0.25 0.25
A-2	$U_m = 2 \times 2 = 4V$ $U_{Rm} = 4 \times 0.25 = 1V \Rightarrow I_m = \frac{U_{Rm}}{R} = \frac{1}{20} = 0.05$ A	0.25 0.75
A-3-a	Current resonance, since u_{AM} and $u_{BM} = Ri$ are in phase	0.25 ;0.25
A-3-b	Since we have current resonance then $LC\omega_o^2 = 1$ so $LC = 6.49\times10^{-6}$.	0.25 ; 0.5
A-4	$U_m = I_m \times R_t \Rightarrow R_t = \frac{4}{0.05} = 80\Omega \Rightarrow r = 80 - 20 = 60\ \Omega$	0.25; 0.25
5- B-1-a	Since u_{BM} reaches its maximum before that of u_{AM}.	0.25
B-1-b	2π rd $\rightarrow$ 8 div $\rightarrow T_0$ $\varphi \rightarrow 1$ div $\Rightarrow \varphi = \frac{2\pi}{8} = \frac{\pi}{4}$ rd.	0.5
B-1-c	$U_{BMmax} = 2.8 \times 0.25 = 0.7$ V $\Rightarrow u_{BM} = 0.7\cos\left(125\pi t + \frac{\pi}{4}\right)$ (u_{BM} in V, t in s) $U_m = 2 \times 2 = 4V \Rightarrow u = 4\cos 125\pi t$ (u in V, t in s).	0.50 0.25
B-2	$I_m = \frac{U_{BMmax}}{R} = \frac{2.8 \times 0.25}{20} = 0.035$ A $\Rightarrow i = 0.035\cos\left(125\pi t + \frac{\pi}{4}\right)$ (i in A, t in s).	0.5
B-3	The law of addition of voltages gives : $u_{AM} = u_{AD} + u_{DB} + u_{BM}$ $4\cos 125\pi t = \frac{8.9 \times 10^{-5}}{C}\sin\left(125\pi t + \frac{\pi}{4}\right) + 80 \times 0.035\cos\left(125\pi t + \frac{\pi}{4}\right)$ For $125\pi t = \frac{\pi}{2}$; $0 = \frac{8.9 \times 10^{-5}}{C}\cos\frac{\pi}{4} - 2.8\sin\frac{\pi}{4} \Rightarrow \frac{8.9 \times 10^{-5}}{C} = 2.8$ $C = \frac{8.9 \times 10^{-5}}{2.8} = 32 \times 10^{-6}$ F = 32 μF.	1
C	$LC = 6.49 \times 10^{-6} \Rightarrow L \times 32 \times 10^{-6} = 6.49 \times 10^{-6} \Rightarrow L = \frac{6.49}{32} = 0.2$ H	0.25

Third exercise (6 points)

Part of the Q	Answer	Mark
1	${}^{14}_{6}C \rightarrow {}^{0}_{-1}e + {}^{A}_{Z}X + {}^{0}_{0}\overline{\nu}$ law of conservation of mass number: 14 = 0 +A +0 then A = 14 law of conservation of charge number:6 = 0-1+Z +0 then Z = 7.	0.25 ; 0.25 ; 0.25 ; 0.25.
2	$\lambda = \frac{0.693}{T} = 1.216\times10^{-4}\,\text{year}^{-1}$	0.75
3	$r = \frac{N(^{14}C)}{N'(^{12}C)} = \frac{N_o(^{14}C)\times e^{-\lambda t}}{N'(^{12}C)}$ with $r_0 = \frac{N_o(^{14}C)}{N'(^{12}C)}$, we can write $r = r_0\, e^{-\lambda t}$.	0.75
4-a	$\frac{r}{r_0} = e^{-\lambda t}$ as t increases then $e^{-\lambda t}$ decreases then $\frac{r}{r_0}$ decreases Since specimen b has the lowest ratio then it is the oldest.	0.5
4-b	$\frac{r}{r_0} = e^{-\lambda t} = 0.843$ then ln 0.843 = – λ× t thus the age of the specimen is $t = \frac{-0.171}{-1.216\times10^{-4}} = 1406.25$ years.	1
5-a	the ratio $\frac{r}{r_0} = e^{-\lambda t}$ fot $t_o = 0$ $\frac{r}{r_0} = 1$; for t= 2T then $\frac{r}{r_0} = 0.25$; for t = 4T then $\frac{r}{r_0} = 0.0625$ for t = 6T then $\frac{r}{r_0} = 0.015625$.	1
5-b		0.5
5-c	Since after millions of years the ratio $\frac{r}{r_0}$ becomes zero so we cannot determine the age of such organism.	0.5

3

This exam is formed of three exercises in three pages numbered from 1 to 3
The use of non-programmable calculator is recommended

First exercise: (7 points)

Charging of a capacitor

In order to charge a capacitor, we connect up the series circuit that is represented in figure 1. This circuit is formed of:

- a generator of constant e.m.f E and of negligible internal resistance;
- a resistor of resistance R;
- a capacitor of capacitance C = 1 μF;
- a switch K.

The capacitor is initially neutral. At the instant $t_0 = 0$, we close K. At an instant t, the armature A carries a charge q and the circuit is traversed by a current i whose direction is shown on the circuit.

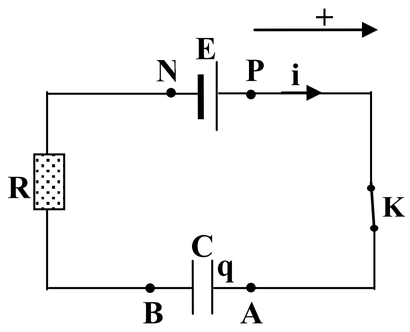


Fig.1

A – Analytical study

1) Write the expression of q in terms of u_{AB} and C.
2) Derive the differential equation that governs the variation of q as a function of time.
3) Using the differential equation , deduce:

a) that the expression of the current at the instant $t_0 = 0$ is $I_0 = \frac{E}{R}$;
b) the expression, of the maximum value Q_m of q in terms of C and E.

B – Exploitation of the curve

The variation of the charge q, as a function of time, is represented by the curve of figure 2. The straight line (OM) represents the tangent to the curve at the instant $t_0 = 0$.
Using figure 2:

1) a) indicate the maximum value Q_m of q ;
b) deduce the value of E.
2) a) Show that the value of I_o is 1 mA;
b) deduce the value of R.
3) Determine the values of u_{AB} and of i at the instant $t_1 = 10^{-2}$s.

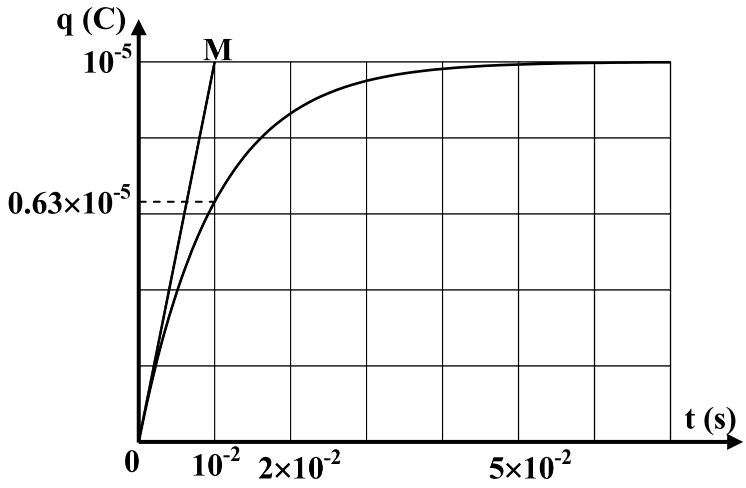


Fig.2

C – Energy stored in the capacitor

Knowing that the energy stored in the capacitor at an instant t is given by $w = \frac{1}{2}\frac{q^2}{C}$, determine:

1) the values of w at $t_0 = 0$ and at $t_1 = 10^{-2}$ s;
2) the average electric power received by the capacitor between t_0 and t_1.

Second exercise: (6 points)

Measurement of the mass of an astronaut

The aim of this exercise is to measure, in a spaceship, the mass of an astronaut using a horizontal mechanical oscillator.

A – Theoretical study

Consider a horizontal mechanical oscillator formed of a solid (S), of mass M, connected to two identical springs of negligible mass and each of stiffness k_1. The center of inertia G of (S) may slide along a horizontal axis x′Ox, where O is confounded with the equilibrium position of G.

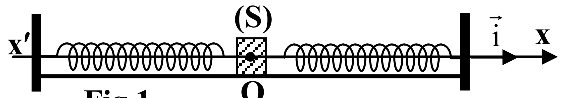


Fig.1

At equilibrium, the two springs are neither compressed nor elongated (Fig.1).

The solid (S), is displaced by a distance x_0 from its equilibrium position in the chosen positive direction, then released without initial velocity at the instant $t_0 = 0$. At an instant t, the abscissa of G is x and the algebraic value of its velocity $\vec{v}$ is $v = \frac{dx}{dt} = x'$.

Neglect all frictional forces, and take the horizontal plane passing through G as a gravitational potential energy reference.

1) Show that the expression of the elastic potential energy of the system [(S), two springs, Earth] is $P.E_e = \frac{1}{2} kx^2$ where $k = 2 k_1$.
2) Write, as a function of k, M, v and x, at an instant t, the expression of the mechanical energy of the system [(S), two springs, Earth].
3) Derive the differential equation, in x, which describes the motion of G.
4) The solution of this differential equation is of the form: $x = A \cos(\omega_0 t + \varphi)$ where A, ω_0 and φ are constants.
   Determine the expressions of A and ω_0 in terms of x_0, M and k and determine the value of φ .
5) Deduce, in terms of M and k_1, the expression of the proper period T_0 of the oscillations of G.

B – Practical study

In spaceships, astronauts measure their masses using a mechanical oscillator as the one above.

An astronaut sits in a chair attached to two identical massless springs each of stiffness $k_1 = 700$ N/m forming a horizontal oscillator (Fig.2).

Let M be the total mass of the astronaut and the chair.

With an appropriate device, we record the variation of the abscissa x of the center of mass of the system [astronaut, chair, 2 springs] as a function of time (Fig.3).

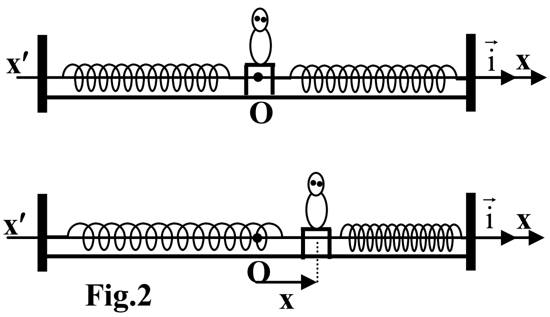


Fig.2

1) Indicate:
   a) the type of the observed oscillations;
   b) the value of the pseudo-period T of these oscillations.
2) The pseudo-period T is approximately equal to the proper period T_0. Conclude.
3) Deduce the mass of the astronaut knowing that the mass of the chair is 6.5 kg.

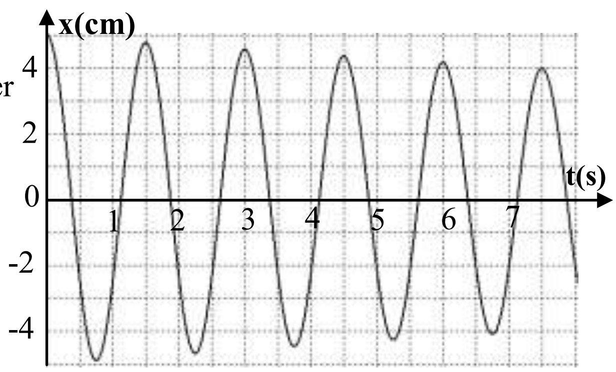


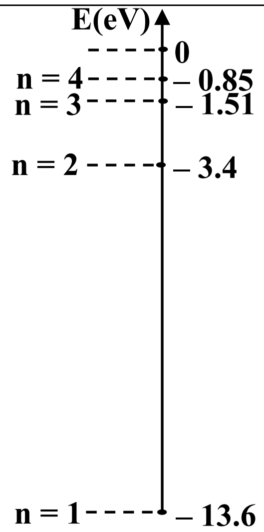
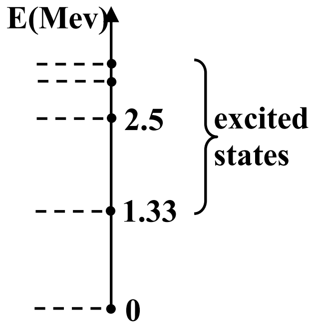
Fig. 3

<u>Third exercise</u>: (7 points)

Energy levels of the hydrogen atom and of the nickel nucleus

The aim of this exercise is to compare and study the energy levels of an atom and a nucleus.

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

Energy diagram of the hydrogen atom	**Energy diagram of the nickel nucleus ^{60}Ni**
	

A – Comparison

Referring to the two diagrams:

1) Name the state corresponding to the energy E = 0 in:

   a) the hydrogen atom;

   b) the nickel nucleus.

2) Show that the transitions of the nickel nucleus are much more energetic than those of the hydrogen atom;

3) Show that the energies of the hydrogen atom and that of the nickel nucleus are quantized.

B – Hydrogen atom

1) The hydrogen atom is in the ground level. Determine the minimum energy needed to ionize this atom.

2) The Lyman series of the hydrogen atom corresponds to a downward transition to the level n =1. Determine the maximum wavelength λ_m of the emitted photons in this series.

3) We send, on a hydrogen atom, separately, three photons a, b and c, whose energies are indicated in the table below, knowing that, in each case, the hydrogen atom is in the ground state.

Photon	a	b	c
Energy in eV	12.09	12.30	14.60

   a) Specify the photons that are absorbed by the hydrogen atom.

   b) Indicate the state of the hydrogen atom in each case.

C – Nickel 60 nucleus

The cobalt isotope $^{60}_{27}Co$, used for the treatment of certain kinds of cancer, is a β^- emitter. The daughter nickel nucleus is found in an excited state ($^{60}_{28}Ni^*$).

1) Write down the equation of the β^- decay of cobalt 60.

2) Write down the equation of the downward transition of Ni^*.

3) Using the energy diagram of the nickel nucleus, determine the maximum wavelength λ'_m of the emitted photon due to the downward transition of the nickel nucleus from an excited state to the ground state.

4) Compare λ'_m and λ_m.

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

First exercise: (7 points)

Part of the Q	Answer	Mark
A.1	$q_A = C\,u_{AB}$.	0.25
A.2	$E = u_{AB} + Ri$ where $i = \frac{dq_A}{dt} \Rightarrow E = \frac{q_A}{C} + R\frac{dq_A}{dt}$.	0.75
A.3.a	At t = 0 ; $q_A = 0$ and $i = \frac{dq_A}{dt} = I_0 \Rightarrow E = RI_0 \Rightarrow I_0 = \frac{E}{R}$.	0.75
A.3.b	When t increases indefinitely q_A tends to a constant value $\Rightarrow \frac{dq_A}{dt} = 0 \Rightarrow Q_m = CE$	0.50
B.1-a	$Q_m = 10^{-5}$ C	0.25
B.1-b	$E = \frac{Q_m}{C} = \frac{10^{-5}}{10^{-6}} = 10$ V	0.25
B.2.a	The slope of the tangent to the curve at the point of abscissa t = 0 is : $I_0 = \frac{10^{-5}}{10^{-2}} = 10^{-3}$ A	0.75
B.2.b	But $I_0 = \frac{E}{R} \Rightarrow R = \frac{E}{I_0} = \frac{10}{10^{-3}} = 10^4$ Ω.	0.50
B.3	At the instant $t = 10^{-2}$ s, we find graphically $q_A = 0.63\times10^{-5}$ C $\Rightarrow u_{AB} = \frac{q_A}{C} = 6.3$V $u_{BN} = E - u_{AB} = 10 - 6.3 = 3.7$ V. $i = \frac{u_{BN}}{R} = 3.7\times10^{-4}$ A.	1.50
C.1	At $t_0 = 0$, $q_0 = 0 \Rightarrow w_0 = 0$ At $t_1 = 10^{-2}$ s, $q_1 = 0.63\times10^{-5}$ C $\Rightarrow w_1 = \frac{1}{2}\frac{q_1^2}{C} = 0.198\times10^{-4}$ J	1.00
C.2	$P_m = \frac{\Delta w}{\Delta t} = 0.198\times10^{-2}$ W	0.50

Second exercise: (7 points)

Part of the Q	Answer	Mark
A.1	The potential energy stored in the spring elongated by x is $P.E_e(1) = ½\, k_1x^2$. The potential energy stored in the spring compressed by x is $PE_e(2) = ½\, k_1x^2$. $\Rightarrow PE_e = P.E_e(1) + P.E_e(2) = ½\, kx^2$ with $k = 2k_1$.	**0.75**
A.2	$ME = ½\, mv^2 + ½\, kx^2$	**0.50**
A.3	No friction, ME = constant $\Rightarrow \frac{dME}{dt} = 0$, $\Rightarrow mv\,v' + kx\,x' = 0 \Rightarrow x'' + \frac{k}{m}x = 0$	**0.75**
A.4	$\dot{x} = -A\omega_0 \sin(\omega_0 t)$ et $x'' = -A\,\omega_0^2 \cos(\omega_0 t)$. By replacing each term by its value, we obtain: $\Rightarrow \omega_0^2 - \frac{k}{m} = 0 \Rightarrow \omega_0 = \sqrt{\frac{k}{m}}$. For t = 0: $x = x_0$ and $v_0 = 0 \Rightarrow x_0 = A\cos\varphi$ and $v_0 = -A.\sin\varphi = 0$; $\Rightarrow \varphi = 0$ or π or $x_0 > 0 \Rightarrow \varphi = 0$ and $x_0 = A$	**1.50**
A.5	The proper period : $T_0 = \frac{2\pi}{\omega_0} = 2\pi\sqrt{\frac{M}{k}} = \pi\sqrt{\frac{2M}{k_1}}$	**0.50**
B.1-a	Free damped oscillations.	**0.25**
B.1-b	The period T = 1.5 s.	**0.50**
B.2	$T = T_0$ because of small damping	**0.25**
B.3	$T_0 = \pi\sqrt{\frac{2M}{k_1}} \Rightarrow M = \frac{k_1 T_0^2}{2\pi^2} \Rightarrow M = 79.87$ kg. The mass of the astronaut is: $M_A = 79.87 - 6.5 = 73.37$ kg.	**1.00**

Third exercise: (6 points)

Part of the Q	Answer	Mark
A.1.a	For an atom: E = 0 corresponds to the ionized state	**0.25**
A.1.b	For a nucleus: E = 0 corresponds to the ground state.	**0.25**
A.2	For an atom, the energy changes are of the order of eV. For a nucleus, the energy changes are of the order of M eV.	**0.50**
A.3	Both have specific values of energy.	**0.25**
B.1	$E_{min} = E_{\infty} - E_1 = 0 + 13.6 = 13.6$ eV.	**0.50**
B.2	$E_{ph} = E_n - E_1$ but $E_{ph} = \frac{hc}{\lambda} \Rightarrow E_{ph\ (min)}$ when λ_{max} then n = 2 so $\frac{6.62\times10^{-34}\times3\times10^{8}}{\lambda_{max}} = E_2 - E_1 = (-3.4 + 13.6)\times1.6\times10^{-19}$ thus $\lambda_m = 1.216\times10^{-7}$m.	**0.75**
B.3.a	$E_{ph} = E_n - E_1$ then $E_n = E_{ph} + E_1$ for photon (a): $E_{ph} = 12.09 \Rightarrow -13.6 + 12.09 = -1,51$ eV $= E_3$ $E_n = -1.51$eV $= E_3$ so this photon is absorbed; for photon (b): $E_{ph} = 12.30 \Rightarrow -13.6 + 12.09 \Rightarrow E_n = -1.3$eV $\neq E_n$ so this photon cannot be absorbed; for photon (c) $E_{ph} = 14.6 > E_1$ so this is absorbed.	**1.50**
B.3.b	For photon (a): 2nd excited state E_3; for photon (b); ground state for photon (c): ionized state.	**0.75**
C.1	${}^{60}_{27}\text{Co} \rightarrow {}^{0}_{-1}\text{e} + {}^{60}_{28}\text{Ni}^*$	**0.50**
C.2	${}^{60}_{28}\text{Ni}^* \rightarrow {}^{60}_{28}\text{Ni} + \gamma$.	**0.25**
C.3	λ'_m corresponds to the smallest energy: $\Delta E = 1.33 - 0 = 1.33$ MeV$= 2.128\times10^{-13}$ J $\lambda'_m = \frac{h.C}{\Delta E} = 9.33\times10^{-13}$ m	**1.00**
C.4	$\frac{\lambda'_m}{\lambda_m} = 7,6\times10^{-6} \Rightarrow \lambda'_m <<<<< \lambda_m$	**0.50**

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الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	

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

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

Applications of the diffraction of light

A – Measurement of the width of a slit

A laser beam of light, of wavelength in vacuum λ= 632.8 nm, falls normally on a vertical slit of width «a». The diffraction pattern is observed on a screen placed perpendicularly to the laser beam at a distance D = 1.5 m from the slit.
Let «L» be the linear width of the central fringe (Fig. 1).
The angle of diffraction θ corresponding to a dark fringe of order n is given by $\sin\theta = \frac{n\lambda}{a}$ where n = ±1, ±2, ±3…
For small angles, take $\tan\theta \approx \sin\theta \approx \theta$ in radian.

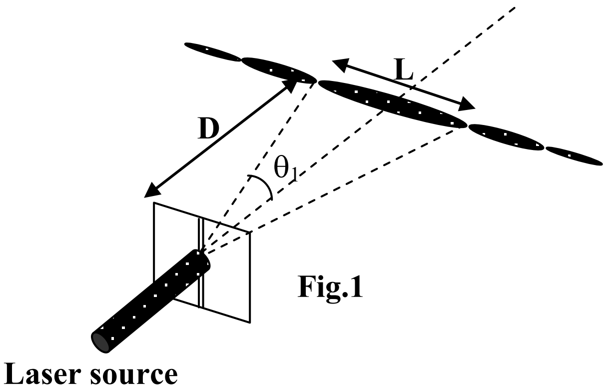


Fig.1

1) Describe the aspect of the diffraction pattern observed on the screen.
2) Write the relation among a, θ_1 and λ.
3) Establish the relation among a, λ , L and D.
4) Knowing that L = 6.3 mm, calculate the width «a» of the used slit.

B – Controlling the thickness of thin wire

A manufacturer of thin wires wishes to control the diameter of his product. He uses the same set-up mentioned in part (A) but he replaces the slit by a thin vertical wire. He observes on the screen the phenomenon of diffraction (figure 2).
For D = 2.60 m, he obtains a central fringe of constant linear width L_1 = 3.4 mm.

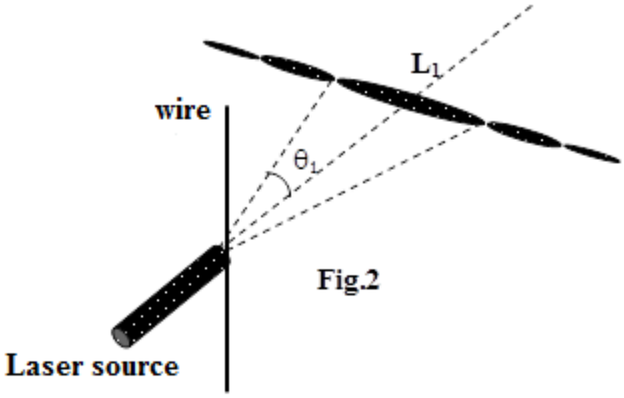


Fig.2

1) Calculate the value of the diameter «a_1» of the wire at the illuminated point.
2) The manufacturer illuminates the wire at different positions under the same precedent conditions. Specify the indicator that permits the manufacturer to check that the diameter of the wire is constant.

C – Measurement of the index of water

We place the whole set-up of part (A) in water of index of refraction n_{water} . We obtain a new diffraction pattern.
We find that for D = 1.5 m and a = 0.3 mm, the linear width of the central fringe is L_2 = 4.7 mm.
1) Calculate the wavelength λ' of the laser light in water.
2) **a)** Determine the relation among λ , λ' and n_{water} .
b) Deduce the value of n_{water} .

<u>Second exercise</u>: (7 points) **Mechanical oscillator**

Consider a mechanical oscillator constituted of a spring, of negligible mass, and of un-joined loops of stiffness k and a solid (S) of mass m = 0.1 kg.
The spring, placed horizontally, is fixed from one of its extremities to a fixed support and (S) is attached to the other extremity. (S) may slide without friction on a horizontal rail AB 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 (Fig. 1).

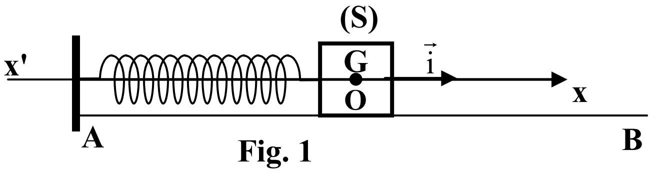


Fig. 1

The solid (S) is displaced from its equilibrium position by a distance $x_0 = \overline{OG_0}$ and we give it, at the instant $t_0 = 0$, in the positive direction an initial velocity $\vec{v}_0 = v_0\vec{i}$. Thus, (S) performs mechanical oscillations along x'Ox.

A – Theoretical study

At the instant t, the abscissa of G is x = $\overline{OG}$ and the algebraic measure of its velocity is v = $\frac{dx}{dt}$.

Take the horizontal plane passing through G as a reference level of gravitational potential energy.

1) Write, at an instant t, the expression of the mechanical energy ME of the system (oscillator, Earth) in terms of m, x, k and v.

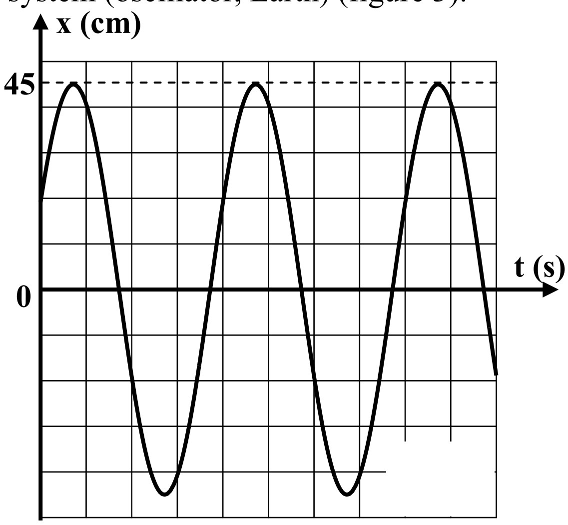
2) Establish the second order differential equation in x that describes the motion of G.

3) The solution of this differential equation has the form: $x = X_m \sin(\frac{2\pi}{T_0}t + \varphi)$, where X_m , T_0 and φ are constants. Determine the expression of the proper period T_0 in terms of m and k.

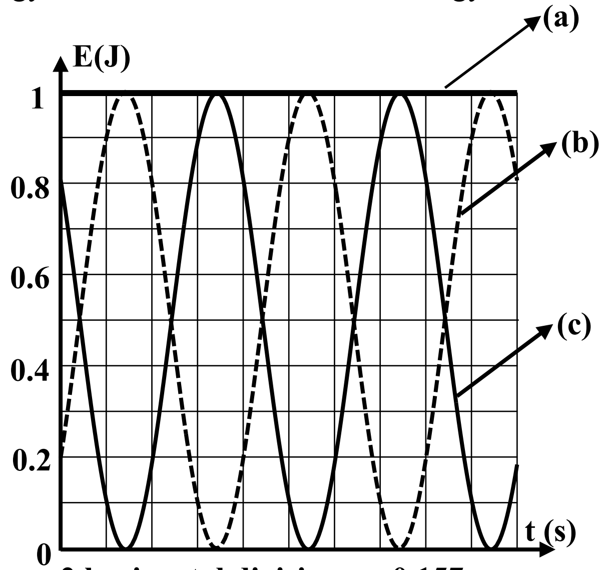
B – Graphical study of the motion

An appropriate device allows to obtain the variations with respect to time:

- of the abscissa x of G (figure 2);
- of the kinetic energy KE, of the elastic potential energy PE_e and of the mechanical energy ME of the system (oscillator, Earth) (figure 3).



1 horizontal division → 0.157 s
1 vertical division → 10 cm



2 horizontal divisions →0.157s **Fig.3**

1) Referring to figure (2), indicate the value of:
  a) the initial abscissa x_0 ;
  b) the amplitude X_m ;
  c) the period T_0.

2) Determine the values of k and φ .

3) The curves (a), (b), and (c) of figure 3 represent the variations of the energies of the system (oscillator, Earth) as a function of time. Using this figure:
  a) identify, with justification, the energy represented by each curve;
  b) determine the value of the initial velocity v_0 ;

c) **i)** indicate the value of the period T of the KE and PE_e;
ii) deduce the relation between T and T_0.

<u>Third exercise</u>: (7 points) Charging and discharging of a capacitor

The aim of this exercise is to determine, by two different methods, the value of the capacitance C of a capacitor. For this aim, we set-up the circuit of figure 1. This circuit is formed of an ideal generator delivering a constant voltage of value E = 10 V, a capacitor of capacitance C, two identical resistors of resistances $R_1 = R_2 = 10\ k\Omega$ and a double switch K.

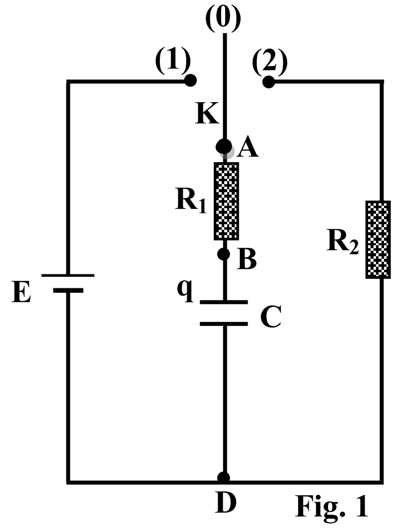


Fig. 1

A – Charging the capacitor

The switch K is in the position (0) and the capacitor is neutral. At the instant $t_0 = 0$, we turn K to position (1) and the charging of the capacitor starts.

1) Theoretical study

a) Applying the law of addition of voltages and taking the positive direction along the circuit as that of the current, show that the differential equation that describes the variation of the voltage $u_C = u_{BD}$ across the capacitor has the form: $E = R_1 C \dfrac{du_C}{dt} + u_C$.

b) The solution of this differential equation has the form: $u_C = A(1 - e^{\frac{-t}{\tau_1}})$ where A and τ_1 are constants. Show that A = E and $\tau_1 = R_1C$.

c) Show that at the end of charging $u_C = E$.

d) Show that the expression $u_{AB} = u_{R_1} = E\ e^{\frac{-t}{R_1C}}$.

e) Establish the expression of the natural logarithm of u_{R_1} [$\ell n\,(u_{R_1})$] as a function of time.

2) Graphical study

The variation of $\ell n\,(u_{R_1})$ as a function of time is represented by figure 2.

a) Justify that the shape of the obtained graph agrees with the expression of $\ell n(u_{R_1})$ as a function of time.

b) Deduce, using the graph, the value of the capacitance C.

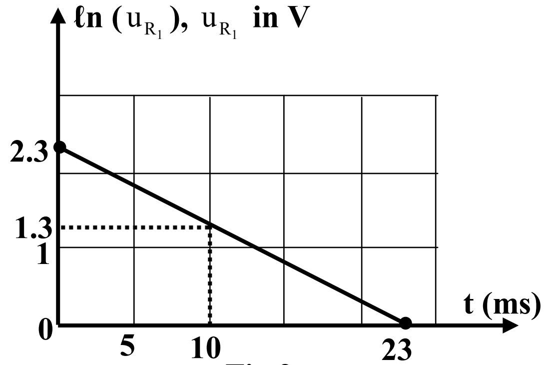


Fig.2

B – Discharging the capacitor

The capacitor being fully charged, we turn the switch K to position (2). At an instant $t_0 = 0$, taken as a new origin of time, the discharging of the capacitor starts.

1) During discharging, the current circulates from B to A in the resistor of resistance R_1. Justify.

2) Taking the positive direction along the circuit as that of the current, show that the differential equation in the voltage u_C across the capacitor has the form: $u_C + (R_1 + R_2)\, C \dfrac{du_C}{dt} = 0$.

3) The solution of the above differential equation has the form: $u_C = Ee^{\frac{-t}{\tau_2}}$ where τ_2 is the time constant of the circuit during discharging. Show that $\tau_2 = (R_1 + R_2)\,C$.

4) The variation of the voltage u_C across the capacitor and the tangent to the curve $u_C = f(t)$ at the instant $t_0 = 0$, are represented in figure 3. Deduce, from this figure, the value of the capacitance C.

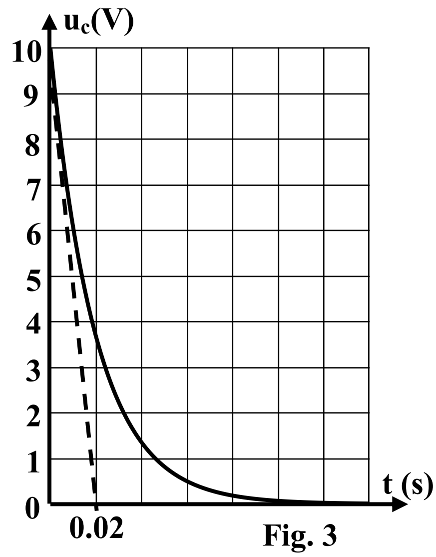


Fig. 3

First exercise (6 points)

Part of the Q	Answer	Mark
A-1	We observe: - alternating bright and dark fringes; - the width of the central fringe is double that of any other bright fringe; - The direction of the pattern of fringes is perpendicular to that of the slit.	¾
A-2	$\sin\theta_1 = \frac{\lambda}{a} \approx \theta_1$	¼
A-3	We have $\tan\theta_1 = \frac{L}{2D}$, for small θ_1, $\tan\theta_1 \approx \theta_1 = \frac{L}{2D}$. and $\sin\theta_1 \approx \theta_1$ so $\frac{\lambda}{a} = \frac{L}{2D}$.	**1**
A-4	$a = \frac{2D\lambda}{L} = \frac{2\times1.5\times632.8\times10^{-9}}{6.3\times10^{-3}} = 3\times10^{-4}$ m = 0.3 mm.	¾
B-1	The diameter of the wire = $\frac{2\times2.6\times632.8\times10^{-9}}{3.4\times10^{-3}}$ $= 0.967\times10^{-3}$ m = 0.967 mm	¾
B-2	The linear width of the central fringe. Because if L = constant $\Rightarrow$ a = constant	½
C.1	Apply the same ralation we obtain : $\frac{\lambda'}{a} = \frac{L_2}{2D}$ $\Rightarrow \lambda' = \frac{aL_2}{2D} = \frac{0.3\times10^{-3}\times4.7\times10^{-3}}{2\times1.5} = 470\times10^{-9}$ m	¾
C-2-a	$\lambda' = \frac{V}{\nu}$ and $\lambda = \frac{C}{\nu}$ $\Rightarrow$ $\frac{\lambda'}{\lambda} = \frac{V}{C} = \frac{1}{n_{water}}$ $\Rightarrow$ $\lambda' = \frac{\lambda}{n_{water}}$	¾
C-2-b	$n_{water} = \frac{\lambda}{\lambda'} = \frac{623.8}{470} = 1.346$	½

Second exercise (7 points)

Part of the Q	Answer	Mark
A-1	$ME = ½\, kx^2 + ½\, mv^2$	**½**
A-2	No friction then $\frac{dME}{dt} = 0 = kxx' + mvv' \Rightarrow x'' + \frac{k}{m}x = 0.$	**¾**
A-3	$x = X_m \sin(\frac{2\pi}{T_0}t + \varphi) \Rightarrow v = \frac{2\pi}{T_0}X_m \cos(\frac{2\pi}{T_0}t + \varphi)$ $\Rightarrow x'' = -(\frac{2\pi}{T_0})^2 X_m \sin(\frac{2\pi}{T_0}t + \varphi)$ $\Rightarrow -(\frac{2\pi}{T_0})^2 X_m \sin(\frac{2\pi}{T_0}t + \varphi) + \frac{k}{m}X_m \sin(\frac{2\pi}{T_0}t + \varphi) = 0$ $\Rightarrow T_0 = 2\pi\sqrt{\frac{m}{k}}$.	**1**
B-1-a	$x_0 = 20$ cm	**¼**
B-1-b	$X_m = 45$ cm	**¼**
B-1-c	$T_0 = 4 \times 0.157 = 0.628$ s	**½**
B-2	$T_0 = 2\pi\sqrt{\frac{m}{k}} \Rightarrow k = \frac{4\pi^2 m}{T_0^{\ 2}}$ $\Rightarrow k = 10$ N/m. For $t_0=0$, $x = x_0 = X_m \sin\varphi \Rightarrow \sin\varphi = \frac{x_0}{X_m} = \frac{20}{45} = 0.44 \Rightarrow \varphi = 0.46$ rad or $\varphi = \pi - 0.46$ rad ; but $v_0 = X_m\,\omega \cos\varphi > 0$ according to figure 2 $\Rightarrow \cos\varphi > 0$ and $\varphi = 0.46$ rad.	**1 ½**
B-3-a	The curve (a) represents ME bacause ME= cte. $PE_{e_0} = ½k(x_0)^2 = ½(10)\times(0.2)^2 = 0.2$ J $\Rightarrow$ (b) represents PE_e. The curve (c) represents KE	**1**
B-3-b	$KE_0 = ½\, m(v_0)^2 = 0.8$ J $\Rightarrow v_0 = 4$ m/s.	**½**
B-3-c-i	$T = 2 \times 0.157 = 0.314$ s	**¼**
B-3-c-ii	$T_0 = 0.628$ s $\Rightarrow T = \frac{T_0}{2}$	**½**

Third exercise (7 points)

Part of the Q	Answer	Mark
A-1-a	$u_{AD} = u_{AB} + u_{BD} \Rightarrow E = R_1 i + u_C$ with $i = C\frac{du_C}{dt}$ we obtain : $E = R_1 C\frac{du_C}{dt} + u_C$	¾
A-1-b	$\frac{du_C}{dt} = \frac{A}{\tau_1} e^{-\frac{t}{\tau_1}}$, Substitute in the differenial equation, we obtain $E = R_1 C\frac{A}{\tau_1} e^{-\frac{t}{\tau_1}} + A(1 - e^{-\frac{t}{\tau_1}}) \Rightarrow E = Ae^{\frac{-t}{R_1C}}(\frac{R_1C}{\tau_1} - 1) + A$ Then A = E and $\tau_1 = R_1.C$	**1**
A-1-c	At the end of the charge , $t \to \infty \Rightarrow e^{-\frac{t}{\tau_1}} \to 0 \Rightarrow u_C = A = E$. <u>or</u> : At the end of thecharge $i = 0 \Rightarrow u_{R1} = 0 \Rightarrow uc = E$	½
A-1-d	$u_{R_1} = R_1 i = R_1 C\frac{du_C}{dt} = R_1 C\frac{E}{\tau_1} e^{-\frac{t}{\tau_1}} = Ee^{\frac{-t}{R_1C}}$ <u>or</u> : $u_G = u_{R_1} + u_C \Rightarrow E = u_{R1} + E - Ee^{\frac{-t}{R1C}} \Rightarrow u_{R_1} = Ee^{\frac{-t}{R_1C}}$	½
A-1-e	$u_{R1} = Ee^{\frac{-t}{R_1C}} \Rightarrow \ln u_{R_1} = \ln E - t/\tau_1$	¼
A-2-a	$\ln(u_R) = \ln E - \frac{t}{R_1C}$ decreasing linearly with time, or it has the form of $\ln(u_R) = at + b$ with $a < 0$.	½
A-2-b	The slope of this straight line is $-\frac{1}{R_1C} = \frac{2.3-1.3}{0-0.01} = -100\ s^{-1} \Rightarrow$ $\frac{1}{R_1C} = 100\ s^{-1}$ and $C = \frac{1}{10^6} F = 1\ \mu F$.	**1**
B-1	Because the armature B of the capacitor is charged positively.	¼
B-2	$u_C = u_{R_1} + u_{R_2} = (R_1+R_2)\, i$ with $i = -C\frac{du_C}{dt}$, we obtain : $u_C + (R_1+R_2)C\frac{du_C}{dt} = 0$.	¾
B-3	replace $u_C = E\,e^{-\frac{t}{\tau_2}}$ in the differential equation, we obtain: $E\,e^{-\frac{t}{\tau_2}} + (R_1+R_2)C(-\frac{E}{\tau_2} e^{-\frac{t}{\tau_2}}) = 0 \Rightarrow \tau_2 = (R_1+R_2)C$	½
B-4	The slope of the tangent to the curve $u_C = f(t)$ at the instant $t_0 = 0$ meets the time axis at a point of abscissa $\tau_2 = 0.02s$ $\tau_2 = (R_1+R_2)C \Rightarrow \frac{0.02}{20000} \Rightarrow C = 10^{-6}F$.	

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المديرية العامة للتربية
دائرة الامتحانات

امتحانات الشهادة الثانوية العامة
الفرع : علوم الحياة

دورة العام 2014 العادية
الاحد 22 حزيران 2014

مسابقة في مادة الفيزياء
المدة ساعتان

الاسم:
الرقم:

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

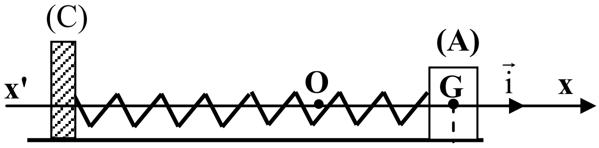
<u>First exercise</u>: (7 points)

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.

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

Identification of two electric components

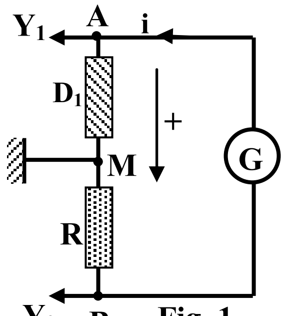


Fig. 1

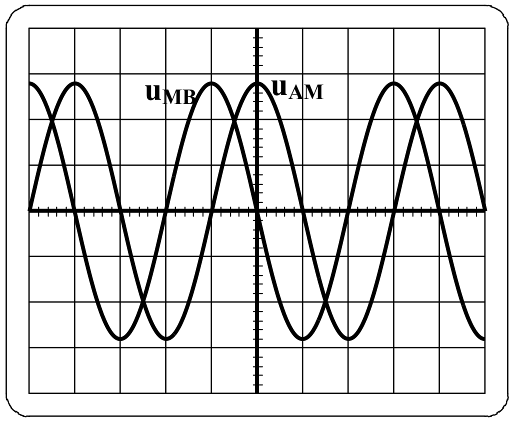
Consider two electric components (D_1) and (D_2), a generator (G) delivering an alternating sinusoidal voltage of angular frequency $\omega = 100\pi$ rd/s and a resistor (R) of resistance $R = 100\ \Omega$. One of the two components is a coil of inductance L and of negligible resistance; the other is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

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.



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

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.

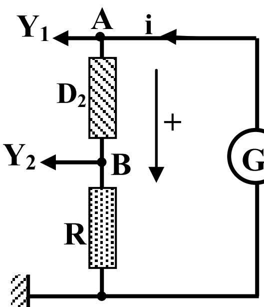


Fig. 3

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

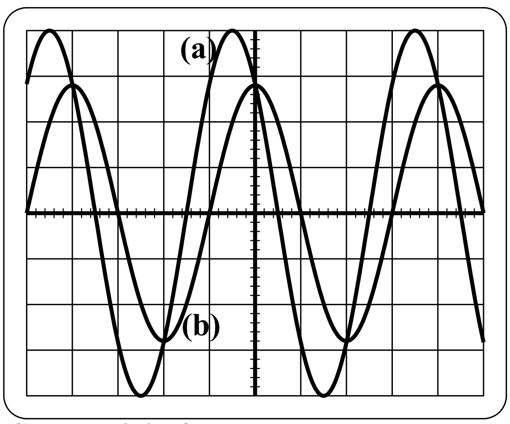
2) Referring to the waveforms of figure 4, determine:

- **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**

Third exercise: (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:

$E_n = -\frac{E_0}{n^2}$, 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 $R_H = \frac{E_0}{hc}$.

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 λ_α = 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 ⇒ $ME = \frac{1}{2}k X_m^2$ ME conserved ⇒ $\frac{1}{2}k X_m^2 = 0.625 \Rightarrow X_m = 0.125m = 12.5$ 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×5 = 14 V = RI_m then $I_m = 0.14$ A	**0.75**
A.2.b	$U_m(D_1) = 2.8$ div×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 ⇒ (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×5 = 14 V = RI_m then $I_m = 0.14$ A	**0.5**
B.2.b	$U_{m(G)} = 4$ div×5 = 20 V	**0.25**
B.2.c	i lags u_{AM}, $\varphi = \frac{2\pi\times0.5\text{div}}{4\text{div}} = \frac{\pi}{4}$ 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	$R_H = \frac{13.6 \times 1.6 \times 10^{-19}}{6.62 \times 10^{-34} \times 3 \times 10^8} = 1.096 \times 10^7$ m^{-1}.	**0.5**
B.3.a	For the wavelength to be maximum, the energy $E = E_n - E_1$ is minimum $\frac{hc}{\lambda_{max}} = E_2 - E_1 \Rightarrow \lambda_{max} = 1.217 \times 10^{-7} m = 121.7 nm$ Or n = 2$\Rightarrow \frac{1}{\lambda_2} = 1.096 \times 10^7 (1 - \frac{1}{2^2}) = 8.217 \times 10^7$ $m^{-1} \Rightarrow$ $\lambda_{max} = 1.217 \times 10^{-7}$ 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**

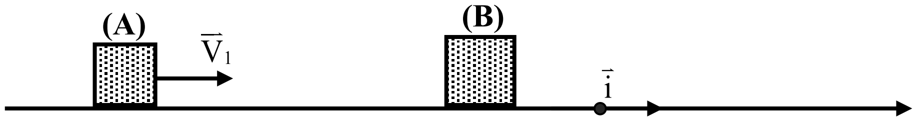
مسابقة في مادة الفيزياء	الاسم:
المدة ساعتان	الرقم:

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

First exercise: (6 points)

Collision and interaction

In order to study the collision between two bodies, we consider a horizontal air table equipped with a launcher and two pucks (A) and (B) of respective masses $m_A = 0.4$ kg and $m_B = 0.6$ kg.
(A), launched with the velocity $\vec{V}_1 = 0.5\ \vec{i}$, collides with (B) initially at rest.
(A) rebounds with the velocity $\vec{V}_2 = -0.1\vec{i}$ and (B) moves with the velocity $\vec{V}_3 = 0.4\vec{i}$ (V_1, V_2 and V_3 are expressed in m/s). Neglect all frictional forces.



A – Linear momentum

1) a) Determine the linear momentums:
i) $\vec{P}_1$ and $\vec{P}_2$ of (A), before and after collision respectively;
ii) $\vec{P}_3$ of (B) after collision.
b) Deduce the linear momentums $\vec{P}$ and $\vec{P'}$ of the system [(A), (B)] before and after collision respectively.
c) Compare $\vec{P}$ and $\vec{P'}$. Conclude.

2) a) Name the external forces acting on the system [(A), (B)].
b) Give the value of the resultant of these forces.
c) Is this resultant compatible with the conclusion in question (1- c)? Why?

B – Type of collision

1) Determine the kinetic energy of the system [(A), (B)] before and after collision.
2) Deduce the type of the collision.

C – Principle of interaction

The duration of collision is $\Delta t = 0.04$ s; we can consider that $\frac{\Delta\vec{P}}{\Delta t} \approx \frac{d\vec{P}}{dt}$.

1) Determine during Δt:
a) the variations $\Delta\vec{P}_A$ and $\Delta\vec{P}_B$ in the linear momentums of the pucks (A) and (B) respectively;
b) the forces $\vec{F}_{A/B}$ exerted by (A) on (B) and $\vec{F}_{B/A}$ exerted by (B) on (A).
2) Deduce that the principle of interaction is verified.

Second exercise: (7 points)

Characteristic of an electric component

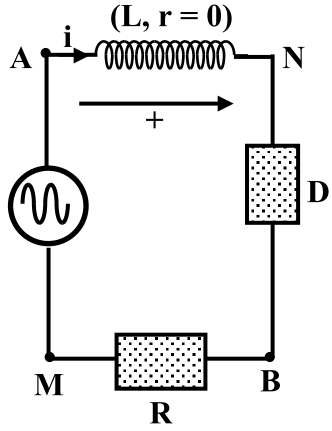


Fig.1

In order to determine the characteristic of an electric component (D), we connect up the circuit represented in figure 1.
This series circuit is composed of: the component (D), a resistor of resistance $R = 100\,\Omega$, a coil (L = 25 mH; r = 0) and an (LFG) of adjustable frequency f maintaining across its terminals a sinusoidal alternating voltage $u = u_{AM}$.

A – First experiment

We connect an oscilloscope so as to display the variation, as a function of time, the voltage u_{AM} across the generator on the channel (Y_1) and the voltage u_{BM} across the resistor on the channel (Y_2).
For a certain value of f, we observe the waveforms of figure 2.
The adjustments of the oscilloscope are:
- ✓ vertical sensitivity: 2 V/div on the channel (Y_1);
  0.5 V/div on the channel (Y_2);
- ✓ horizontal sensitivity: 1 ms/ div.

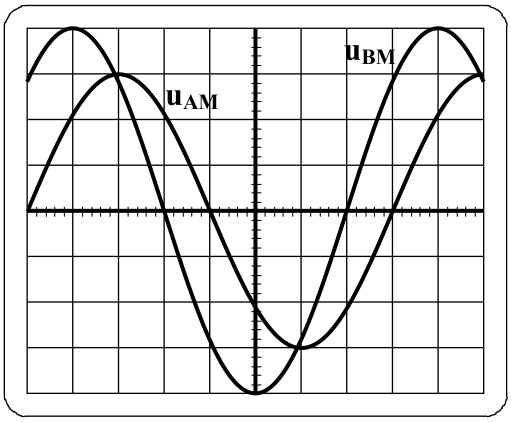


Fig.2

1) Redraw figure 1 and show on it the connections of the oscilloscope.

2) Using figure 2, determine:

a) the value of f and deduce the value of the angular frequency ω of u_{AM};
b) the maximum value U_m of the voltage u_{AM};
c) the maximum value I_m of the current i in the circuit;
d) the phase difference φ between u_{AM} and i. Indicate which one leads the other.

3) (D) is a capacitor of capacitance C. Justify.

4) Given that: $u_{AM} = U_m \sin \omega t$. Write down the expression of i as a function of time.

5) Show that the expression of the voltage across the capacitor is:

$$u_{NB} = -\frac{0.02}{250\pi C}\cos\left(\omega t + \frac{\pi}{4}\right) \quad (u_{NB} \text{ in V ; C in F ; t in s})$$

6) Applying the law of addition of voltages and by giving t a particular value, determine the value of C.

B – Second experiment

The effective voltage across the generator is kept constant and we vary the frequency f . We record for each value of f the value of the effective current I.

For a particular value $f = f_0 = \dfrac{1000}{\pi}$ Hz, we notice that I admits a maximum value.

1) Name the phenomenon that takes place in the circuit for the frequency $f = f_0$.

2) Determine again the value of C.

Third exercise: (7 points)

Nuclear reactions

Given: mass of a proton: $m_p = 1.0073$ u; mass of a neutron: $m_n = 1.0087$ u;
mass of ${}^{235}_{92}U$ nucleus = 235.0439 u; mass of ${}^{90}_{36}Kr$ nucleus = 89.9197 u;
mass of ${}^{142}_{Z}Ba$ nucleus =141.9164 u; molar mass of ${}^{235}_{92}U$ = 235 g/mole;
Avogadro's number: $N_A = 6.022\times10^{23}$ mol^{-1}; 1u = 931.5 MeV/c^2 = 1.66×10^{-27} kg; 1 MeV = 1.6×10^{-13} J.

A – Provoked nuclear reaction

As a result of collision with a thermal neutron, a uranium 235 nucleus undergoes the following reaction:

$${}^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{90}_{36}Kr + {}^{142}_{Z}Ba + y\,{}^{1}_{0}n$$

1) **a)** Determine y and z .
b) Indicate the type of this provoked nuclear reaction.

2) Calculate, in MeV, the energy liberated by this reaction.

3) In fact, 7% of this energy appears as a kinetic energy of all the produced neutrons.
a) Determine the speed of each neutron knowing that they have equal kinetic energy.
b) A thermal neutron, that can provoke nuclear fission, must have a speed of few km/s; indicate then the role of the "moderator" in a nuclear reactor.

4) In a nuclear reactor with uranium 235, the average energy liberated by the fission of one nucleus is 170 MeV.
a) Determine, in joules, the average energy liberated by the fission of one kg of uranium ${}^{235}_{92}U$.
b) The nuclear power of such reactor is 100 MW. Calculate the time Δt needed so that the reactor consumes one kg of uranium ${}^{235}_{92}U$.

B – Spontaneous nuclear reaction

1) The nucleus krypton ${}^{90}_{36}Kr$ obtained is radioactive. It disintegrates into zirconium ${}^{90}_{40}Zr$, by a series of β^- disintegrations.
a) Determine the number of β^- disintegrations.
b) Specify, without calculation, which one of the two nuclides ${}^{90}_{36}Kr$ and ${}^{90}_{40}Zr$ is more stable.

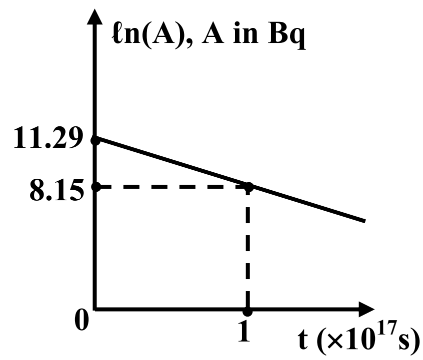
2) Uranium ${}^{235}_{92}U$ is an α emitter.
a) Write down the equation of disintegration of uranium ${}^{235}_{92}U$ and identify the nucleus produced.
Given:

Actinium ${}_{89}Ac$	Thorium ${}_{90}Th$	Protactinium ${}_{91}Pa$

b) The remaining number of nuclei of ${}^{235}_{92}U$ as a function of time is given by: $N = N_0 e^{-\lambda t}$ where N_0 is the number of the nuclei of ${}^{235}_{92}U$ at $t_0 = 0$ and λ is the decay constant of ${}^{235}_{92}U$.
i) Define the activity A of a radioactive sample.
ii) Write the expression of A in terms of λ, N_0 and time t.

c) Derive the expression of $\ell n(A)$ in terms of the initial activity A_0, λ and t.

d) The adjacent figure represents the variation of $\ell n(A)$ of a sample of ${}^{235}_{92}U$ as a function of time.



i) Show that the shape of the graph, in the adjacent figure, agrees with the expression of $\ell n(A)$.
ii) Using the adjacent figure determine, in s^{-1}, the value of the radioactive constant λ.
iii) Deduce the value of the radioactive period T of ${}^{235}_{92}U$.

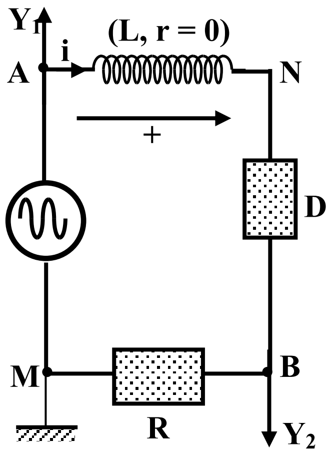
3

الدورة العادية للعام 2015	امتحانات الشهادة الثانوية العامة الفرع : علوم الحياة	وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات
الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	مشروع معيار التصحيح

First exercise (6 points)

Part of the Q	Answer	Mark
A.1.a.i	$\vec{P}_1 = m_A \vec{V}_1 = 0.4 \times (0.5\ \vec{i}\,) = 0.2\ \vec{i}$ (kg m/s). $\vec{P}_2 = m_A \vec{V}_2 = 0.4 \times (-0.1\ \vec{i}\,) = -0.04\,\vec{i}$ (kg m/s).	¾
A.1.a.ii	$\vec{P}_3 = m_B\ \vec{V}_3 = 0.6 \times (0.4\,\vec{i}\,) = 0.24\ \vec{i}$.	¼
A.1.b	$\vec{P} = \vec{P}_1 + 0 = 0.2\ \vec{i}$. $\vec{P}' = \vec{P}_2 + \vec{P}_3 = -0.04\,\vec{i} + 0.24\ \vec{i} = 0.2\,\vec{i}$.	½
A.1.c	$\vec{P} = \vec{P}'$. Conclusion: the linear momentum of the system [(A), (B)] is conserved during collision.	½
A.2.a	The external forces acting on the system are: The weight $\overrightarrow{m_A g}$ and the normal reaction of the air table $\vec{N}_A$. the weight $\overrightarrow{m_B g}$ and the normal reaction of the air table $\vec{N}_B$.	½
A.2.b	We have : $\overrightarrow{m_A g} + \vec{N}_A + \overrightarrow{mg_B} + \vec{N}_B = \vec{0}$ The sum of the external forces acting on the system (A, B) is thus zero.	½
A.2.c	Yes, Since the system [(A),(B)] is isolated.	¼
B.1	$KE_{before} = ½\, m_A(V_1)^2 + 0 = 0.05$ J. $KE_{after} = ½\, m_A(V_2)^2 + ½\, m_B(V_3)^2 = 0.05$ J.	1
B.2	$KE_{before} = KE_{after} \Rightarrow$ collision is elastic.	¼
C.1.a	$\Delta\overrightarrow{P_A} = \overrightarrow{P_2} - \overrightarrow{P_1} = -0.24\,\vec{i}$. $\Delta\overrightarrow{P_B} = \overrightarrow{P_3} - \vec{0} = 0.24\ \vec{i}$.	½
C.1.b	$\dfrac{\Delta\vec{P}_A}{\Delta t} = \vec{F}_{B/A} = \dfrac{-0.24\vec{i}}{0.04} = -6\,\vec{i}$ (N) . $\dfrac{\Delta\vec{P}_B}{\Delta t} = \vec{F}_{A/B} = \dfrac{0.24\vec{i}}{0.04} = 6\,\vec{i}$ (N).	¾
C.2	$\vec{F}_{B/A} = -\ \vec{F}_{A/B}$ $\Rightarrow$ the principle of [interaction] is thus verified.	+

Second exercise (7 points)

Part of the Q	Answer	Mark
A.1		½
A.2.a	T = 8 ms $\Rightarrow$ f = 125 Hz. $\omega = 2\pi f = 250\pi$ rad/s.	**1**
A.2.b	$U_m = 3\times 2 = 6$ V.	+
A.2.c	$U_{m(R)} = 0.5\times 4 = 2\text{ V} \Rightarrow I_m = \dfrac{U_m(R)}{R} = 2\times 10^{-2}$ A	¾
A.2.d	$\lvert\varphi\rvert = \dfrac{2\pi}{8} = \dfrac{\pi}{4}$ rad ; i leads u_{AM}	¾
A.3	i leads u_{AM} $\Rightarrow$ (D) is a capcitor	+
A.4	$i = 2\times 10^{-2}\ \sin(250\pi t + \dfrac{\pi}{4})$ (i in A and t in s)	½
A.5	$i = C\dfrac{du_{NB}}{dt} \Rightarrow u_{NB} = \dfrac{1}{C}\int i\,dt = \dfrac{1}{C}\int 0.02\sin(\omega t + \dfrac{\pi}{4})dt$ $\Rightarrow u_{NB} = -\dfrac{0.02}{250\pi C}\cos(250\pi t + \dfrac{\pi}{4})$	¾
A.6	$U_m\sin(\omega t) = L\omega I_m\cos(\omega t + \dfrac{\pi}{4}) - \dfrac{0.02}{250\pi C}\cos(250\pi t + \dfrac{\pi}{4}) + 2\sin(\omega t + \dfrac{\pi}{4})$ $t = 0 \Rightarrow 0 = L\omega I_m\dfrac{\sqrt{2}}{2} - \dfrac{0.02}{250\pi C}\times\dfrac{\sqrt{2}}{2} + 2\dfrac{\sqrt{2}}{2} \Rightarrow C = 1.06\times 10^{-6}$ F	**1.25**
B.1	Current resonance	+
B.2	$f_0 = \dfrac{1}{2\pi\sqrt{LC}} \Rightarrow C = 1.06\times 10^{-6}$ F	¾

Third exercise (7 points)

Part of the Q	Answer	Mark
A.1.a	Conservation of charge number: $92 + 0 = 36 + z + 0$ thus $z = 56$ Conservation of mass number: $235 + 1 = 90 + 142 + y$ thus $y = 4$	¾
A.1.b	Fission nuclear reaction	¼
A.2	$\Delta m = [m_U + m_n] - [m_{Kr} + m_{Ba} + 4m_n]$ $= 235.0439 - [89.9197 + 141.9164 + 3\times1.0087] = 0.1817$ u $E = \Delta mc^2 = [0.1817\times931.5 \text{ Mev/c}^2]\, c^2 = 169.253$ MeV	¾
A.3.a	K.E of each neutron $= \dfrac{169.253\times\frac{7}{100}}{4} = 2.96$ MeV $= 2.96\times1.6\times10^{-13}$ $K.E = 4.739\times10^{-13}$ J $K.E = ½\, mV^2$ then $V = \sqrt{\dfrac{2KE}{m}} = \sqrt{\dfrac{2\times4.739\times10^{-13}}{1.0087\times1.66\times10^{-27}}}$ $V = 2.379\times10^{7}$ m/s = 23790 km/s.	½
A.3.b	A moderator will help in reducing their speed so as to provoke more such reactions	¼
A.4.a	$N = \dfrac{\text{mass}}{\text{molar mass}}\times N_A = \dfrac{1000}{235}\times6.02\times10^{23} = 2.5617\times10^{24}$ nuclei. $E = 170\times1.6\times10^{-13}\times2.5617\times10^{24} = 6.97\times10^{13}$ J	½
A.4.b	$E = P\times\Delta t \Rightarrow \Delta t = \dfrac{6.97\times10^{13}}{10^{8}} = 6.97\times10^{5}$ s = 8 days	½
B.1.a	${}^{90}_{36}Kr \rightarrow {}^{90}_{40}Zr + a\,{}^{0}_{-1}\beta$ $a = 4$	¼
B.1.b	A non-stable nucleus decays into a more stable one thus ${}^{90}_{40}Zr$ is more stable	¼
B.2.a	${}^{235}_{92}U \rightarrow {}^{4}_{2}He + {}^{A}_{Z}X$, $A = 231$ and $Z = 90 \Rightarrow$ X is thorium	½
B.2.b.i	The activity is the number of decays per unit time	¼
B.2.b.ii	$A = \lambda N = \lambda N_0 e^{-\lambda t}$	¼
B.2.c	$\ell n(A) = -\lambda t + \ell n(A_0)$.	½
B.2.d.i	$\ell n(A) = -\lambda t + \ell n(A_0)$ is a straight line of negative slope $\Rightarrow$ compatible with the graph.	½
B.2.d.ii	$\lambda = -$ slope of curve $= 3.14\times10^{-17}\ s^{-1}$,	½
B.2.d.iii	$\lambda = \dfrac{\ell n(2)}{T} \Rightarrow T = 22.0747\times10^{15}$s $= 7\times10^{8}$ years.	½

مسابقة في مادة الفيزياء — الاسم:
المدة ساعتان — الرقم:

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

First exercise: (7 points)

The flash of a camera

The electronic flash of a camera is made primarily of a capacitor of capacitance C, a flash lamp and of an electronic circuit which transforms the constant voltage E = 3 V provided by two dry cells into a constant voltage U_0 = 300 V. The aim of this exercise is to show the importance of the electronic circuit in the electronic flash of a camera.

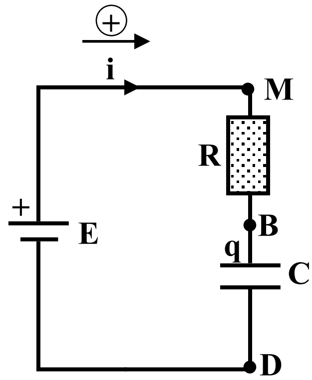


Fig. 1

A – Determination of the value of the capacitance C of the capacitor

To determine the value of the capacitance C of the capacitor, we connect the circuit of figure 1 where the resistor has a large resistance R, the DC generator maintains across its terminals a constant voltage E = 3 V. An appropriate device allows to plot the curve representing the variations of the current i as a function of time. The capacitor, being uncharged, at the instant $t_0 = 0$, we close the circuit. We obtain the graph of figure 2.

1) **a)** Determine the expression of the current i in terms of C and the voltage $u_C = u_{BD}$ across the terminals of the capacitor.

b) By applying the law of addition of voltages, determine the differential equation of the voltage u_C.

2) The solution of this differential equation is given by:

$u_C = E(1 - e^{-\frac{t}{\tau}})$ where $\tau = RC$.

a) Determine, as a function of time t, the expression of the current i.

b) Deduce, at the instant $t_0 = 0$, the expression of the current I_0 in terms of E and R.

c) Using figure 2:

i) calculate the value of the resistance R of the resistor;

ii) determine the value of the time-constant τ of the circuit.

d) Deduce that $C \approx 641$ μF.

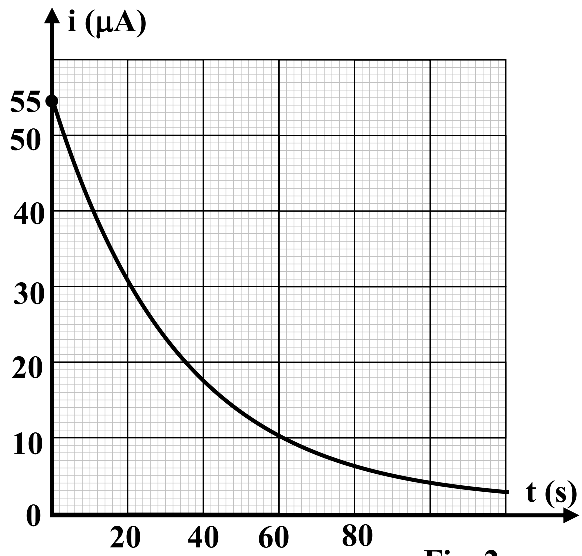


Fig. 2

B – Energetic Study

1) Show that the electric energy stored in the capacitor, when it is completely charged under the voltage E is $W \approx 2.9 \times 10^{-3}$ J.

2) The capacitor, being totally charged, is disconnected from the circuit and discharges through a resistor of same resistance R. Calculate:

a) the duration at the end of which the capacitor can be practically completely discharged ;

b) the average power given by the capacitor during the discharging process.

C – The flash of the camera

The discharge in the flash lamp causes a flash of duration approximately one millisecond .

1) Determine the value of the average electric power P_e consumed by this flash if the capacitor is charged under the voltage:

- **a)** $E = 3$ V ;
- **b)** $U_0 = 300$ V.

2) Explain why it is necessary to raise the voltage before applying it across the terminals of the capacitor.

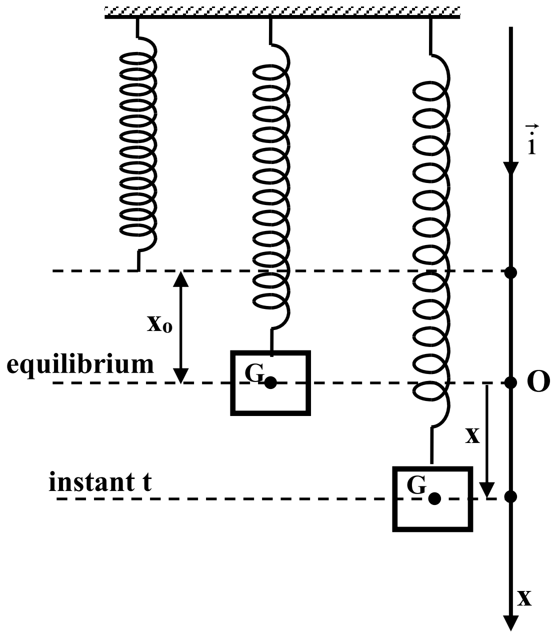
<u>Second exercise</u>: (7 points)

Measurement of the gravitational acceleration

In order to measure the gravitational acceleration, we consider a spring of stiffness k and of negligible mass, connected from its upper end to a fixed support while its other end carries a solid (S) of mass m. At equilibrium the center of mass G of (S) coincides with a point O and the spring elongates by $\Delta\ell_o = x_o$ (adjacent figure).

We denote by g the gravitational acceleration.

The spring is stretched by pulling (S) vertically downwards from its equilibrium position, then releasing it without initial velocity at instant $t_o = 0$. G oscillates around its equilibrium position O. At an instant t, G is defined by its abscissa $x = \overline{OG}$ and the algebraic value of its velocity is $v = \dfrac{dx}{dt}$.



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

A – Static study

1) Name the external forces acting on (S) at the equilibrium position.

2) Determine a relation among m, g, k and x_o.

B – Energetic study

1) Write, at an instant t, the expression of the :

- **a)** kinetic energy of (S) in terms of m and v;
- **b)** elastic potential energy of the spring in terms of k , x and x_o ;
- **c)** gravitational potential energy of the system [(S), Earth] in terms of m, g and x.

2) Show that the expression of the mechanical energy of the system [(S), spring, Earth] is given by:

$$ME = \frac{1}{2}mv^2 + \frac{1}{2}k(x + x_o)^2 - mgx.$$

3) **a)** Applying the principle of the conservation of the mechanical energy, show that the differential equation in x that describes the motion of G has the form of : $x'' + \dfrac{k}{m}x = 0$.

b) Deduce the expression of the proper period T_o of the oscillator in terms of m and k.

c) Show that the expression of T_o is given by: $T_o = 2\pi\sqrt{\dfrac{x_0}{g}}$.

C – Experimental study

For different solids of different masses suspended to the same spring, we measure using a stop watch the corresponding values of T_o . The results are collected in the following table:

m (g)	20	40	60	80	100
x_o (cm)	4	8	12	16	20
T_o (s)	0.4	0.567	0.693	0.8	0.894
T_o^2 (s^2)	0.16		0.48	0.64	

1) Complete the table.

2) Plot the curve giving the variations of x_o as a function of T_o^2.

Scale : on the abscissa-axis: 1cm represents 0.16 s^2

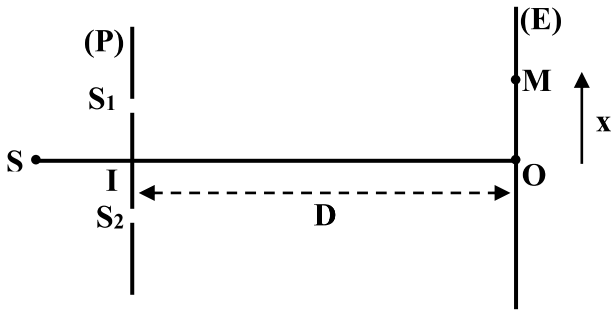
on the ordinate –axis: 1cm represents 4 cm.

3) Determine the slope of this curve and, using the expression $T_o = 2\pi\sqrt{\frac{x_0}{g}}$, deduce the value of the gravitational acceleration.

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

Interference of light

Consider Young's double slit apparatus that is represented in the adjacent figure. S_1 and S_2 are separated by a distance a = 1 mm.
The planes (P) and (E) are at a distance D = 2 m. I is the midpoint of [S_1S_2] and O is the orthogonal projection of I on (E). On the perpendicular to IO at point O and parallel to S_1S_2, a point M is defined by its abscissa OM = x.



The optical path difference δ at M ($\overline{OM}$ = x), located in the interference region on the screen of observation is: $\delta = SS_2M - SS_1M = \frac{ax}{D}$.

A – The source S emits a monochromatic light of wavelength λ in air.

1) The phenomenon of interference of light shows evidence of an aspect of light. Name this aspect.

2) Indicate the conditions for obtaining the phenomenon of interference of light.

3) Describe the interference fringes that observed on (E).

4) Determine the expression giving the abscissa of the centers of the bright fringes and that of the centers of the dark fringes.

5) Deduce the expression of the interfringe distance in terms of λ, D and a.

B – The source S emits white light which contains all the visible radiations of wavelengths λ in vacuum or in air where: 400 nm (violet) ≤ λ ≤ 800 nm (red).

1) The obtained central fringe is white. Justify.

2) Compare the positions of the centers of the first bright fringes corresponding to red and violet colors on the same side of O.

3) The point M has an abscissa x = 4 mm.

a) Show that the wavelengths of the radiations that reach M in phase are given by: λ (in nm) = $\frac{2000}{k}$, k being a non- zero positive integer.

b) Determine the wavelengths of these radiations.

C – The source S emits two radiations of wavelengths λ_1 = 450 nm and λ_2 = 750 nm.
Determine the abscissa x of the nearest point to O, where two dark fringes coincide.

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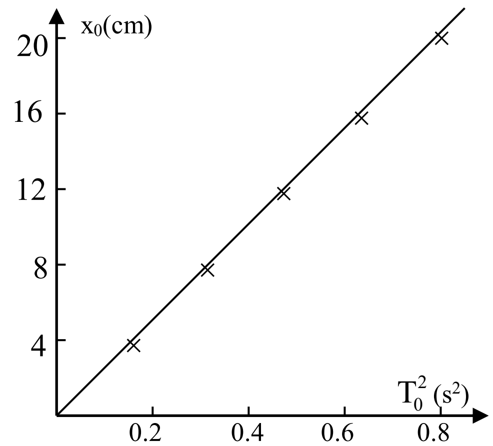
الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	مشروع معيار التصحيح

First exercise (7 points)

Part of the Q	Answer	Mark
A.1.a	The expression of i: $i = \frac{dq}{dt} = C\frac{du_C}{dt}$	0.5
A.1.b	$u_{MD} = u_{MB} + u_{BD} \Rightarrow E = Ri + u_C \Rightarrow E = RC\frac{du_C}{dt} + u_C$	0.5
A.2.a	$i = C\frac{du_C}{dt} = C\frac{E}{RC}e^{-\frac{t}{\tau}}, \Rightarrow\ i = \frac{E}{R}e^{-\frac{t}{\tau}}$.	0.5
A.2.b	At the instant $t_0 = 0$, $I_0 = \frac{E}{R}$.	0.25
A.2.c.i	At the instant $t_0 = 0$, $I_0 = 55\ \mu A \Rightarrow R = 54545.45\ \Omega$.	0.5
A.2.c.ii	For $i = 0.37\ I_0 = 20.35 \approx 20\ \mu A$, $t = \tau = 35$ s.	0.75
A.2.d	$\tau = RC \Rightarrow C = 641\ \mu F$.	0.5
B.1	Electric energy $W = ½\ CE^2 = ½ \times 641\times 10^{-6}\times 9 = 2,9\times10^{-3}$J	0.5
B.2.a	The duration: $\Delta\tau = 5\tau = 175$ s.	0.5
B.2.b	The average power of the discharge : $\frac{W}{\Delta t} = \frac{2.9\times10^{-3}}{175} = 1.65\times10^{-5}$ W	0.75
C.1.a	$W_1 = ½\ CE^2 = 2.9\times10^{-3}J \Rightarrow P_1 = \frac{W_1}{t} = 2.9$ W.	0.5
C.1.b	$W_2 = ½\ C U_0^2 = 28.845J \Rightarrow P_2 = \frac{W_2}{t} = 28845$ W	0.75
C.3	To increase the power consumed by the flash lamp during discharge.	0.5

Second exercise (7 points)

Part of the Q	Answer	Mark
A.1	The weight $m\vec{g}$ and the force of tension $\vec{T}$ in the spring	**0.5**
A.2	At equilibrium, $\vec{T} = -m\vec{g} \Rightarrow T = mg \Rightarrow mg = k\,x_0$.	**0.75**
B.1.a	$KE = \frac{1}{2} mV^2$	**0.25**
B.1.b	$PE_{el} = \frac{1}{2} k(x+x_o)^2$	**0.25**
B.1.c	$PE_g = -\ mgx$	**0.25**
B.2	$ME = KE + PE_{el} + PE_g$ $ME = \frac{1}{2} mV^2 + \frac{1}{2} k(x+x_o)^2 - mgx$.	**0.25**
B.3.a	ME is conserved $\Rightarrow \frac{dME}{dt} = 0 \Rightarrow \frac{1}{2} m2vx'' + \frac{1}{2} k2(x + x_o)\, v - mgv = 0$ $\Rightarrow V\,(\,mx'' + kx_o - mg + kx\,) = 0$ But $V \neq 0$ and $mg = kx_o$ therefore $x'' + \frac{k}{m} x = 0$.	**1**
B.3.b	This differential equation is of the form $x'' + \omega_o^2\, x = 0$ therefore : $\omega_o = \sqrt{\frac{k}{m}}$ and $T_o = \frac{2\pi}{\omega_0} = 2\pi \sqrt{\frac{m}{k}}$	**1**
B.3.c	$mg = kx_o \Rightarrow \frac{m}{k} = \frac{x_o}{g} \Rightarrow T_o = 2\pi \sqrt{\frac{x_0}{g}}$	**0.5**
C.1	The missed values are :0.321; 0.799 .	**0.5**
C.2	See figure 	**0.5**
C.3	The curve is a straight line passing through the origin. The slope is : $a = \frac{x_0}{T_0^2} = 0.25\ m/s^2$. On the other hand : $T_0^2 = 4\pi^2 \frac{x_0}{g}$ and $g = 4\pi^2 \frac{x_0}{T_0^2}$ $\Rightarrow g = 9.86\ m/s^2$.	**1.25**

Third exercise (6 points)

Part of the Q	Answer	Mark
A.1	The wave aspect of light	**0.5**
A.2	The two sources S_1 and S_2 are monochromatic and coherent	**0.5**
A.3	We observe interference fringes : - alternate bright and dark fringes ; - rectilinear and equidistant - parallel of $S_1$and S_2	**0.5**
A.4	Bright fringe: $\delta = k\lambda = \frac{ax}{D} \Rightarrow x = \frac{k\lambda D}{a}$. Dark fringe: $\delta = (2k+1) = \frac{ax}{D} \Rightarrow x = \frac{(2k+1)\lambda D}{2a}$	**1**
A.5	$i = x_{k+1} - x_K = (k+1)\frac{\lambda D}{a} - \frac{k\lambda D}{a} = \frac{\lambda D}{a}$	**0.5**
B.1	each radiation of the white light gives out at O a bright fringe; the superposition of all radiation at O gives the white color	**0.5**
B.2	$x_v = k\frac{\lambda_v D}{a}$ et $x_R = k\frac{\lambda_R D}{a} \Rightarrow \lambda_R > \lambda_v \Rightarrow x_R > x_v$	**0.5**
B.3.a	$x = \frac{k\lambda D}{a} \Rightarrow 4\times10^6 \text{(in nm)} = \frac{k\lambda\times2\times10^9}{1\times10^6} \Rightarrow \lambda \text{ (in nm)} = \frac{2000}{k}$	**0.5**
B.3.b	$400 \leq \lambda = \frac{2000}{k} \leq 800 \Rightarrow$ $2.5 \leq k \leq 5 \Rightarrow k = 3$, 4 and 5 $\Rightarrow \lambda_1 = \frac{2000}{3} = 667$ nm ; $\lambda_2 = \frac{2000}{4} = 500$ nm; $\lambda 3_2 = \frac{2000}{5} = 400$ nm .	**0.75**
C	The abscissa of points on the screen where the radiations arrive in opposition of phase is: $x = \frac{(2k+1)\lambda D}{2a} \Rightarrow$ $\frac{(2k_1+1)\lambda_1 D}{2a} = \frac{(2k_2+1)\lambda_2 D}{2a} \Rightarrow$ $\frac{(2k_1+1)\lambda_1 D}{2a} = \frac{(2k_2+1)\lambda_2 D}{2a} \Rightarrow \frac{(2k_1+1)}{(2k_1+1)} = \frac{\lambda_2}{\lambda_1} = \frac{5}{3}$; $\lambda_1 < \lambda_2 \Rightarrow k_1 > k_2$; $900k_1 + 450 = 1500\ k_2 + 750 \Rightarrow 3k_1 - 5k_2 = 1$. This equation is verified for $k_1 = 2$ and $k_2 = 1$ (first solution) $x \text{ (in mm)} = \frac{(4+1)450\times10^{-6}\times2\times10^3}{2\times1} = 2.25$ mm.	**0.75**

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مسابقة في مادة الفيزياء المدة ساعتان	الاسم: الرقم:

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

<u>First exercise</u>: (7 points)

Harmonic oscillator

The aim of this exercise is to study the motion of a mechanical oscillator.

A – Theoretical study

For this aim, consider a small trolley (C) of mass m = 200 g, attached to one extremity of a horizontal spring (R); of negligible mass, and of un-jointed loops of stiffness k = 20 N/m; the other extremity of the spring is attached to a fixed support (A) (figure 1).

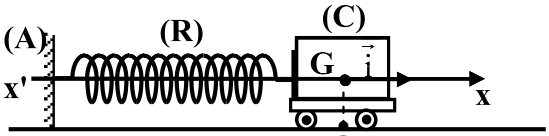

Fig.1

The trolley (C) may slide without friction on a horizontal rail and its center of inertia G can move along the horizontal axis x'Ox.

At the instant $t_0 = 0$, (G) is initially in its equilibrium position O, at this instant (C) is launched, at the instant $t_0 = 0$, with an initial velocity $\vec{V_o} = -V_0\,\vec{i}$ ($V_0 > 0$). (C) then oscillates without friction with a proper angular frequency ω_0.

At an instant t, the abscissa of G is $x = \overline{OG}$ and the algebraic measure of its velocity is $v = \frac{dx}{dt}$.

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

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

2) Derive the second order differential equation in x that describes the motion of G.

3) The solution of this differential equation is of the form $x = -X_m \sin(\omega_0 t)$, where X_m is a positive constant.

   a) Determine the expression of ω_0 in terms of k and m.

   b) Deduce the value of the proper period T_0.

4) Determine the expression of the amplitude X_m in terms of V_0, k and m.

B – Energetic study

An appropriate device allows to obtain the variations with respect to time of the kinetic energy , elastic potential energy and the mechanical energy of the system [(C), (R), Earth] (figure 2).

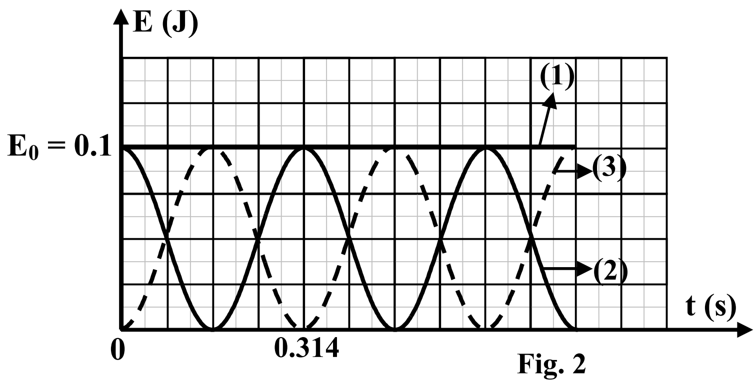

Fig. 2

1) Indicate, with justification, the type of energy corresponding to each curve.

2) The energies represented by the curves (2) and (3) are periodic of period T.

   a) Pick up from figure 2 the value of T.

   b) Deduce the relation between T and T_0.

3) Write the expression of E_0 in terms of m and V_0.

4) Deduce the value of V_0.

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

Determination of the characteristics of an electric component

An electric component (D), of unknown nature, which may be a resistor of resistance R or a pure coil of inductance L or a capacitor of capacitance C.

To determine the nature and the characteristic of (D) we consider the following:

- An ideal generator G of constant electromotive force (e.m.f) E;
- Two resistors of resistances $R_1 = 100\ \Omega$ and $R_2 = 150\ \Omega$;
- A double switch K.

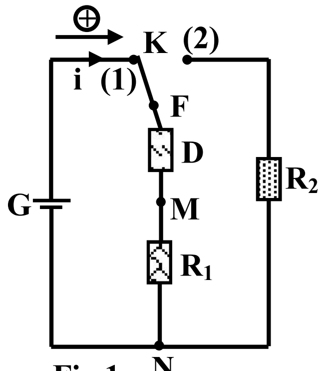

Fig.1

We set up the circuit of figure 1.

A – First Experiment

At an instant $t_0 = 0$, the switch K is turned to position (1). Figure 2 shows the variation of the voltage u_{FM} across the terminals of (D) as a function of time and the tangent to this curve at $t_0 = 0$.

1) The component (D) is a capacitor. Justify.

2) Indicate the value of the e.m.f E of the generator.

3) Calculate, at $t_0 = 0$, the current carried by the circuit.

4) Derive the differential equation describing the variation of the voltage $u_{FM} = u_C$.

5) The solution of the differential equation has the form:

$u_C = u_{FM} = A + B\ e^{-\frac{t}{\tau}}$.

Determine the expressions of the constants A, B and τ in terms of R_1, C and E.

6) Determine, graphically, the value of the time constant τ .

7) Deduce the value of C.

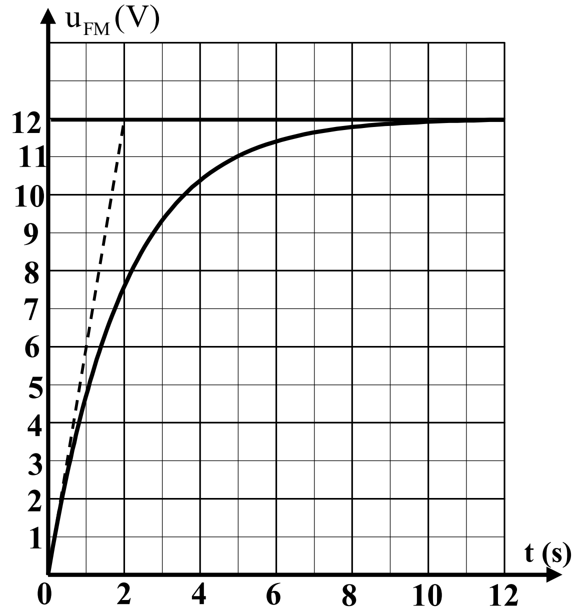

Fig. 2

B – Second Experiment.

During the charging of the capacitor and at an instant t_1, we turn the switch K to the position (2) (figure 3).

1) Name the phenomenon that takes place.

2) The resistor R_2 can support a maximum power of $P_{max} = 0.24$ W.

a) Calculate the maximum value of the current which can pass through R_2 without damaging it (the thermal power is given by the relation: $p = R\ i^2$).

b) Applying the law of addition of voltages, show that the maximum voltage across the terminals of the capacitor is $u_{FM} = 10$ V so that R_2 will not be damaged.

c) At the instant t_1 the current is maximum. Determine, graphically, the maximum duration $\Delta t = t_1$ of the charging process of the capacitor so that the resistor R_2 will not be damaged.

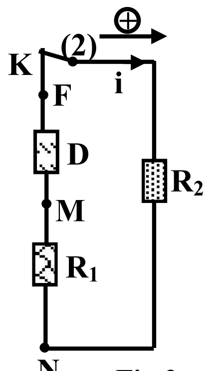

Fig.3

Third exercise: (6 points)

The radioactivity of cobalt-60

The cobalt isotope ${}^{60}_{27}Co$ is radioactive of a radioactive constant $\lambda = 4.146\times10^{-9}$ s^{-1}. Consider a sample of this isotope of mass m_0 = 1 g at the instant t_0 = 0.

Given:

Symbol	${}^{60}_{27}Co$	${}^{60}_{28}Ni$	${}^{A}_{Z}X$
Mass (in u)	59.9190	59.9154	0.00055

- 1u = 931.5 MeV/c² ;
- Avogadro's number: 6.02×10^{23} mol^{-1};
- Molar mass of cobalt: 60 $g.mol^{-1}$;
- 1 year = 365 days.

1) Calculate, in years, the period of the cobalt- 60 nucleus.

2) **a)** Determine, at t_0 = 0, the number of nuclei N_0 presented in 1 g of cobalt- 60.

b) Define the activity A of a radioactive sample.

c) Determine the activity of the cobalt sample at the instant t = 15.9 years.

3) The disintegrations of ${}^{60}_{27}Co$ gives rise to a nickel isotope ${}^{60}_{28}Ni$ according to the following reaction:

$${}^{60}_{27}Co \rightarrow {}^{60}_{28}Ni + {}^{A}_{Z}X + ...$$

a) Calculate, specifying the laws used, A and Z.

b) Name the emitted particles.

c) Calculate, in MeV, the energy liberated by this disintegration.

d) Determine the energy liberated by the disintegration of 1g of cobalt- 60.

4) Knowing that the energy liberated by the fission of 1 g of ${}^{235}_{92}U$ is 5.127×10^{23} Mev, calculate the mass of ${}^{235}_{92}U$ whose fission provides an energy equivalent to that liberated by the disintegration of 1 g of cobalt-60.

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

First exercise : Harmonic oscillator		7
A.1	Mecahnical energy : ME = PE_{el} + KE $\Rightarrow$ ME = $\frac{1}{2}k\cdot x^2 + \frac{1}{2}m\cdot v^2$	½
A.2	No friction$\Rightarrow$ mechanical energy is conserved $\Rightarrow$ME = constant. Derive both sides with respect to time $\Rightarrow \frac{dME}{dt} = k\,x\,x' + m\,vv' = 0 \Rightarrow x'' + \frac{k}{m}x = 0$.	¾
A.3.a	$x = -X_m \sin(\omega_0 t)$; $x' = -X_m\,\omega_0 \cos(\omega_0 t)$ and $x'' = X_m\,\omega_0^2 \sin(\omega_0 t)$ Replace in the differential equation: $X_m\,\omega_0^2 \sin(\omega_0 t) - \frac{k}{m} X_m \sin(\omega_0 t) = 0 \Rightarrow Xm \sin(\omega_0 t)\,(\,\omega_0^2 - \frac{k}{m}) = 0 \Rightarrow \omega_0 = \sqrt{\frac{k}{m}}$.	1
A.3.b	$T_0 = \frac{2\pi}{\omega_0} = 2\pi\sqrt{\frac{m}{K}} = 0.2\pi = 0.628s$	3/4
A.4	$x' = -X_m\,\omega_0 \cos(\omega_0 t)$; at $t_0 = 0$: $x = 0$ and $v = -X_m\,\omega_0 = -V_0$ $\Rightarrow X_m = \frac{V_0}{\omega_0} = V_0\sqrt{\frac{m}{k}}$. **<u>OR</u>** : Mecahnical energy is conserved $\Rightarrow \frac{1}{2}kX_m^2 = \frac{1}{2}mV_0^2 \Rightarrow X_m = V_0\sqrt{\frac{m}{k}}$	¾
B.1	**Curve (1):** Mechanical energy, because ME = E_0 = constant; **Curve (2) :** Kinetic energy because at t = 0 : v = – V_0 and KE= $\frac{1}{2}m\,V_0^2$ $\Rightarrow$E = E_0 = KE_{max} **Curve (3):** elastic potential energy because at t = 0, x = 0 $\Rightarrow$ PE_{el} = 0	1 ½
B.2.a	T = 0.314s	¼
B.2.b	$T_0 = 2T$	½
B.3	$E_0 = KE_0 + PE_{el} = \frac{1}{2}mV_0^2 + 0 = \frac{1}{2}mV_0^2$	½
B.4	$0.1 = \frac{1}{2}\times 0.2\times V_0^2 \Rightarrow V_0 = 1$ m/s	½

Second exercise : Identification and determination the characteristic of an electric component		7
A.1	D is a capacitor since its voltage increases exponentially from zero to a constant limiting value.	½
A.2	At the end of charging, the voltage across C is E thus: E = 12V	½
A.3	At t = 0 s, the current is maximum, $i = I_0 \Rightarrow E = u_c + R_1 i$; $u_C = 0$ $\Rightarrow i = I_0 = \frac{E}{R_1} = \frac{12}{100} = 0.12$ A.	1
A.4	$u_{FN} = u_{FM} + u_{MN}$: $E = u_{FM} + R_1 . i$ But $i = \frac{dq}{dt} = C\frac{du_{LM}}{dt}$ $\Rightarrow E = u_C + R_1C\frac{du_C}{dt} \Rightarrow \frac{du_C}{dt} + \frac{1}{R_1C}u_C = \frac{E}{R_1C}$	1 ½
A.5	$u_C = A + B\ e^{-\frac{t}{\tau}}$. at $t = 0 \Rightarrow 0 = A + B \Rightarrow A = -B$ $\frac{du_C}{dt} = -\frac{B}{\tau}e^{-t/\tau} \Rightarrow -\frac{B}{\tau}e^{-t/\tau} + \frac{A}{R_1C} + \frac{B}{R_1C}e^{-t/\tau} = \frac{E}{R_1C}$ By identification A = E and $\tau = R_1C$; B = – A = – E	½
A.6	Using the graph, we get : τ = 2 s ; the tangent at t=0, cuts the E-axis at t = 2ms	½
A.7	$\tau = R_1C \Rightarrow C = \frac{2}{100} = 0.02F = 20$ mF.	½
B.1	Discharging of the capacitor	¼
B.2.a	$P_{max} = 0.24\ W = R_2[I_{max}]^2 \Rightarrow I_{max} = 0.04$ A	½
B.2.b	$u_{FM} = u_{FN} + u_{NM} \Rightarrow u_{FM} = R_2i + R_1i = (R_2 + R_1)\ i \Rightarrow (u_{FM})_{max} = (R_2 + R_1)\ I_{max} = 10$ V	½
B.2.c	From the graph $u_C = 10V \Rightarrow t_1 = 0.35s$.	¼

Third exercise : The radioactivity of cobalt-60		6
1	$\lambda = \frac{\ell n}{T} \Rightarrow T = \frac{0.693}{4.146\times10^{-9}\times365\times24\times3600} = 5.3$ years	¾
2.a	$N_0 = \frac{m_0}{M}\times6.02\times10^{23} = 1.00333\times10^{22}$ nuclei $\approx 1\times10^{22}$ nuclei	¾
2.b	The radioactive activity is the number of disintegrations per unit time.	½
2.c	$A = \lambda N$ with $N = N_0 e^{-\lambda t}$; $t = 3T \Rightarrow N = 1.25\times10^{21}$ nuclei $A = \lambda N = 5.2\times10^{12}$ Bq	1
3.a	${}^{60}_{27}Co \longrightarrow {}^{60}_{28}Ni + {}^{A}_{Z}X + \gamma + {}^{0}_{0}\bar{\nu}$ Conservation of charge number: $27 = 28 + Z, \Rightarrow Z = -1$. Conservation of mass number: $60 = 60 + A \Rightarrow A = 0$.	¾
3.b	The emitted particles: electron and antineutrino	½
3.c	$\Delta m = m_{before} - m_{after} = (59.9190) - (59.9154 + 0.00055) = 3.05\times10^{-3}$ u $E_\ell = \Delta mc^2 = 3.05\times10^{-3}\times931.5 = 2.84$ MeV	¾
3.d	Energy liberated by 1 g de Co: $E' = N_0E_\ell = 2.84\times10^{22}$ MeV	½
4	$m_U = \frac{2.84\times10^{22}}{5.127\times10^{23}} = 0.055g$	½

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المديرية العامة للتربية
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امتحانات الشهادة الثانوية العامة
الفرع : علوم الحياة

دورة العام 2016 الإستثنائية
الخميس 4 اب 2016

مسابقة في مادة الفيزياء
المدة: ساعتان

الاسم:
الرقم:

<u>This exam is formed of three exercises in three pages.</u>
<u>The Use of non-programmable calculators is recommended.</u>

<u>First exercise</u>: (7 points)

Characteristics of a coil

The aim of this exercise is to determine the characteristics of a coil. For this aim we set up the circuit represented in figure 1.
This series circuit is composed of: a resistor of resistance R = 40 Ω, a coil of inductance L and of internal resistance r, a capacitor of capacitance C = 5 μF and an (LFG) of adjustable frequency f maintaining across its terminals an alternating sinusoidal voltage: $u(t) = u_{NM} = U_m \cos \omega t$ (u_{NM} in V, t in s).

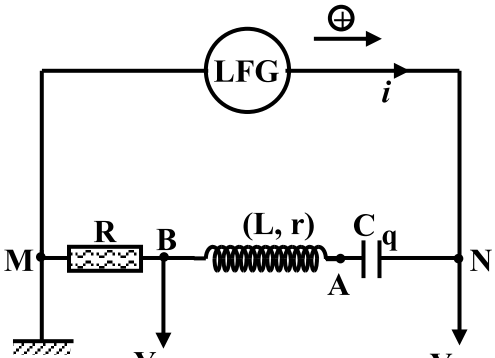

Fig. 1

We connect an oscilloscope to display the variation, as a function of time, of the voltage u_{NM} across the generator on channel (Y_1) and the voltage u_{BM} across the terminals of the resistor on channel (Y_2).
For a certain value of f , we observe the waveforms of figure 2.
The adjustments of the oscilloscope are:

- Horizontal sensitivity: 1 ms/div.
- Vertical sensitivity for both channels: 1 V/div.

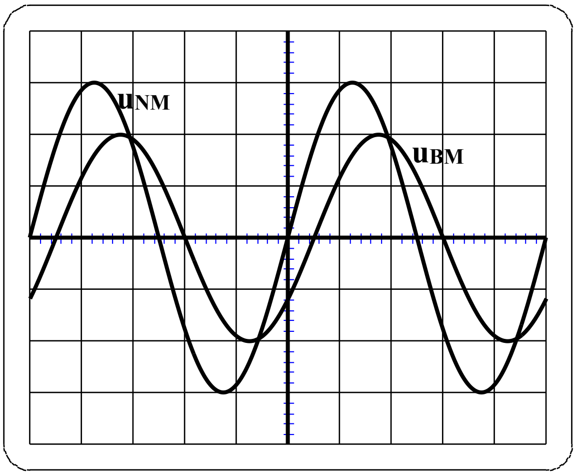

Fig. 2

1) Using the waveforms of figure 2, determine:
  a) the period and the angular frequency ω of the voltage u_{NM};
  b) the maximum value U_m of the voltage across the terminals of the generator;
  c) the maximum value $U_{R(m)}$ of the voltage across the terminals of the resistor and deduce the maximum value I_m of the current i in the circuit;
  d) the phase difference φ between the voltage u_{NM} and the voltage u_{BM}.

2) Write the expression of the current i as a function of time.

3) **a)** Show that the average power consumed by the circuit is $P_{average} = 0.06$ W.
  b) Deduce that r = 8 Ω.

4) **a)** Show that the expression of the voltage across the terminals of the capacitor is:

$$u_{NA} = \frac{25}{\pi}\sin(\omega t - 0.2\pi) \quad (u_{NA} \text{ in V ; t in s}).$$

  b) Determine the expression of the voltage u_{AB} across the terminals of the coil in terms of L and t.

  c) Applying the law of addition of voltages and by giving t a particular value, determine the value of L.

Second exercise: (7 points)

Nature of a collision

The aim of this exercise is to determine the nature of a collision between two objects.
For this aim, an object (A), considered as a particle, of mass $m_A = 2$ kg, can slide without friction on a path situated in a vertical plane and formed of two parts: a circular part DN and a horizontal rectilinear part NM.

(A) is released, without initial velocity, from the point D situated at a height $h_D = 0.45$ m above the horizontal part NM (Fig.1).

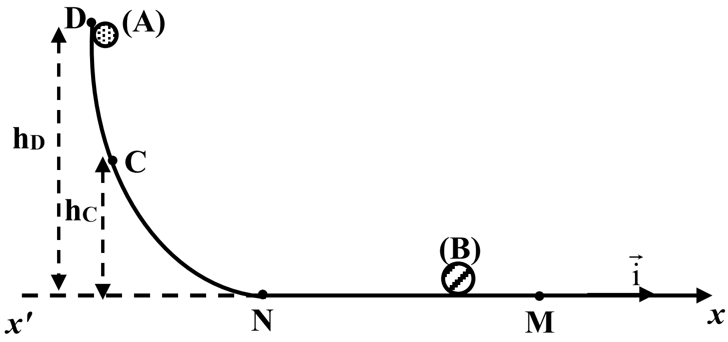

Fig. 1

The horizontal plane passing through MN is taken as the reference level of gravitational potential energy. Take $g = 10$ m/s^2.

1) Calculate the mechanical energy of the system [(A), Earth] at the point D.
2) Deduce the speed V_{1A} of (A) when it reaches the point N.
3) (A) reaches N and moves along NM with the same velocity $\vec{V}_{1A} = V_{1A}\,\vec{i}$. Another object (B), considered as a particle, of mass $m_B = 4$ kg moves along the horizontal path from M toward N with the velocity $\vec{V}_{1B} = -1\,\vec{i}$ (V_{1B} in m/s).
   a) Determine the linear momentum $\vec{P}_S$ of the system [(A), (B)] before collision.
   b) Deduce the velocity $\vec{V}_G$ of the center of inertia G of the system [(A), (B)].

4) After collision, (A) rebounds and attains a maximum height $h_C = 0.27$ m.
   a) Determine the mechanical energy of the system [(A), Earth] at the point C.
   b) Deduce the speed V_{2A} of (A) just after collision.

5) Determine, by applying the principle of the conservation of the linear momentum of the system [(A), (B)], the velocity $\vec{V}_{2B}$ of (B) just after collision.

6) Specify the nature of the collision.

Third exercise: (6 points)

Determination of the volume of the blood of a person by radioactivity

In order to determine the volume of the blood of a person, we use the radionuclide sodium $^{24}_{11}Na$.

Given:

- Planck's constant: $h = 6.63\times10^{-34}$ J.s;
- Speed of light in vacuum: $c = 3\times10^{8}$ m/s;
- Avogadro's number: $N_A = 6.02\times10^{23}$ mol^{-1};
- Molar mass of sodium 24: M = 24 g;
- 1 MeV = 1.6×10^{-13}J.
- Selection from the periodic table:

Element	Fluorine	Neon	Sodium	Magnesium	Aluminium
Nuclide	$^{19}_{9}F$	$^{20}_{10}Ne$	$^{23}_{11}Na$	$^{24}_{12}Mg$	$^{27}_{13}Al$

A – Sodium $^{24}_{11}Na$ is obtained by bombarding the sodium $^{23}_{11}Na$ by a neutron.

1) Write the equation of this nuclear reaction.

2) This reaction is provoked. Justify.

B – The sodium 24 is radioactive β^- emitter.

1) Write the equation of this disintegration.

2) Name the obtained daughter nucleus.

3) The disintegration of sodium 24 is accompanied by the emission of a dangerous radiation γ.

a) Indicate the nature of this radiation.

b) Indicate the cause of the emission of this radiation.

c) One of the emitted photons has energy of 3 MeV. Calculate the wavelength of the corresponding radiation.

C – The radioactive constant of sodium 24 is $\lambda = 1.28\times10^{-5}$ s^{-1}.

1) At the instant $t_0 = 0$, we inject a solution containing $m_0 = 2.4\times10^{-4}$ g of sodium 24 into the blood of a person. Calculate the number of nuclei N_0 of sodium 24 in the injected solution.

2) Calculate, at the instant t = 6 hours, the number of sodium 24 nuclei remaining in the blood of the person.

3) Suppose that the sodium 24 is uniformly distributed in the blood of the person. At the instant t = 6 hours, 10 mL of blood taken from the person contains 9.03×10^{15} nuclei of sodium 24. Calculate the volume of the blood of the person.

دورة العام 2016 الإستثنائية **الخميس 4 اب 2016**	امتحانات الشهادة الثانوية العامة الفرع : علوم الحياة	وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات
الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ساعتان	**مشروع معيار التصحيح**

First exercise (7 points)

Part of the Q	Answer	Note
1.a	$T = 5\text{ div} \times 1\text{ ms/div} = 5\text{ ms} = 5\times10^{-3}\text{s}$ $\omega = \frac{2\pi}{T} = 400\pi\text{ rad/s} = 1256\text{ rad/s}.$	1
1.b	$U_m = 3\text{ div.} \times 1\text{ V/div} = 3\text{ V}$	0.5
1.c	$U_{Rm} = 2\text{ div.} \times 1\text{ V/div} = 2\text{ V}$; $U_{Rm} = R\,I_m \Rightarrow I_m = \frac{2}{40} = 0.05\text{ A}$	0.5 0.5
1.d	$\varphi = \frac{2\pi\times0.5}{5} = 0.2\pi$ rad. u_R lags u_g by 0.2π	0.5
2	$i = 0.05\cos(400\pi t - 0.2\pi)$	0.5
3.a	$P = UI\cos\varphi = \frac{3\times0.05}{\sqrt{2}\times\sqrt{2}}\cos0.2\pi = 0.06\text{ W}$	0.75
3.b	$P = (R+r)I^2 \Rightarrow (R+r) = \frac{P}{I^2} = \frac{0.06}{\frac{(0.05)^2}{2}} = 48\ \Omega \Rightarrow r = 8\,\Omega$	0.5
4.a	$i = C\frac{du_C}{dt} \Rightarrow u_C = \frac{1}{C}\int idt = \frac{0.05}{400\pi C}\sin(400\pi t - 0.2\pi) = \frac{25}{\pi}\sin(400\pi t - 0.2\pi)$	0.75
4.b	$u_{coil} = ri + L\frac{di}{dt} = 0.4\cos(400\pi t - 0.2\pi) - 20\pi L\sin(400\pi t - 0.2\pi)$;	0.75
4.c	$u_{NM} = u_{NA} + u_{AB} + u_{BM}$ with $u_R = Ri = 2\cos(400\pi t - 0.2\pi)$; $3\cos(400\pi t) = \frac{25}{\pi}\sin(400\pi t - 0.2\pi) + 0.4\cos(400\pi t - 0.2\pi) -$ $20\pi L\sin(400\pi t - 0.2\pi) + 2\cos(400\pi t - 0.2\pi)$ For $t = 0$: $3 = 1.94 - 4.68 + 36.91\,L \Rightarrow L = 0.155$ H	0.75

Second exercise (7 points)

Part of Q	Answer	Note
1	$ME_{(D)} = KE_{(D)} + PE_{g(D)} = 0 + m_A g h_D = 9J$	**0.5**
2	No friction $\Rightarrow$ mechanical energy of the system [(A), Earth] is conserved : $ME_{(D)} = ME_{(N)}$; $0 + m_A g h_D = \frac{1}{2} m_A V_{1A}^2 \Rightarrow V_{1A}^2 = 2gh_D \Rightarrow V_{1A} = 3$ m/s.	**1**
3- a	Linear momentum of the system [(A), (B)] before collision: $\vec{P}_S = m_A \vec{V}_{1A} + m_B \vec{V}_{1B} = (2\times 3\,\vec{i}\,) + [4\times(-1\,\vec{i}\,)] = 2\,\vec{i}$ (kg m/s)	**0.75**
3.b	$\vec{P}_S = \vec{P}_G = (m_A + m_B)\,\vec{V}_G \Rightarrow 2\,\vec{i} = 6.\vec{V}_G \Rightarrow \vec{V}_G = 1/3\,\vec{i} = 0.33\,\vec{i}$ (m/s)	**0.75**
4.a	$ME_{(C)} = KE_{(C)} + PE_{g(C)} = 0 + m_A g h_C = 2\times10\times0.27 = 5.4$ J.	**0.75**
4.b	Conservation of the mechanical energy of the system [(A), Earth] $0 + m_A g h_C = \frac{1}{2} m_A V_{2A}^2 \Rightarrow V_{2A}^2 = 2gh_C \Rightarrow V_{2A} = \sqrt{5.4} = 2.323$ m/s.	**0.75**
5	Conservation of the linear momentum of the system [(A), (B)] : $m_A \vec{V}_{2A} + m_B \vec{V}_{2B} = 2\,\vec{i}$ (m/s) $2\times(-2.33\,\vec{i}\,) + 4\,\vec{V}_{2B} = 2\,\vec{i} \Rightarrow (-2.33\,\vec{i}\,) + 2\,\vec{V}_{2B} = \vec{i}$ $\Rightarrow 2\,\vec{V}_{2B} = \vec{i} + 2.323\,\vec{i} = 3.323\,\vec{i} \Rightarrow \vec{V}_{2B} = 1.66\,\vec{i}$ (m/s)	**1.25**
6	The kinetic enegy of the system [(A), (B)] $KE_{before} = \frac{1}{2} m_A V_{1A}^2 + \frac{1}{2} m_B V_{1B}^2 = 11$ J $KE_{after} = \frac{1}{2} m_A V_{2A}^2 + \frac{1}{2} m_B V_{2B}^2 = 5.4 + \frac{1}{2}\times4\times(1.66)^2 = 5.4 + 5.58 = 10.91$ J ≈ 11 J $\Rightarrow$ the collision is elastic	**1.25**

Third exercise (6 points)

Part of the Q	Answer	Note
A.1	${}^{23}_{11}Na + {}^{1}_{0}n \rightarrow {}^{24}_{11}Na$	**0.5**
A.2	Provoked since it needs an external intervention.	**0.5**
B.1	${}^{24}_{11}Na \rightarrow {}^{A}_{Z}X + {}^{0}_{-1}e + {}^{0}_{0}\bar{\upsilon} + \gamma$ The laws of conservation give: 24 = A and 11 = Z – 1 ⇒ Z = 12.	**0.75**
B.2	The daughter nucleus is magnesium: ${}^{24}_{12}Mg$	**0.5**
B.3.a	It is an electromagnetic wave.	**0.5**
B.3.b	Due to the des-excitation of the daughter nucleus	**0.5**
B.3.c	The energy of the photon is : $E = h\frac{c}{\lambda} \Rightarrow \lambda = h\frac{c}{E}$ $\lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{3\times1.6\times10^{-13}} = 4.14\times10^{-13}\,m$	**0.75**
C.1	$N_o = \frac{m_0\,N_A}{M} = 6.02 \times 10^{18}$ nuclei.	**0.75**
C.2	The number of nuclei remaining in the blood of the person is: $N = N_o\,e^{-\lambda t} = 6.02 \times 10^{18} \times e^{-1.28\times10^{-5}\times6\times3600} = 4.56 \times 10^{18}$ nuclei. **Another method** : $t = n.\,T$; $T = \ln2/\lambda \Rightarrow n = 6/15$ $N = N_0/2^n = 4.56 \times 10^{18}$ nuclei	**0.75**
C.3	The volume of blood of the person is : $V = \frac{4.56\times10^{18}\times10^{-2}}{9.03\times10^{15}} = 5.05\ L$.	**0.5**

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المدة: ساعتان | الرقم:

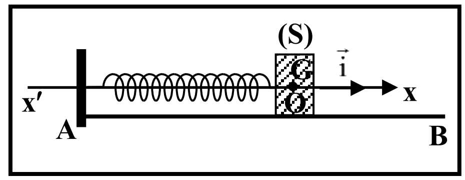
This exam is formed of three exercises in four pages.
The use of non-programmable calculator is recommended.

Exercise 1: (6 points) **Mechanical oscillator**

Consider a mechanical oscillator formed of a massless spring of stiffness k and a solid (S) of mass m = 0.4 kg.

The aim of this exercise is to determine the stiffness k of the spring by two different methods. For this aim, the spring is placed horizontally, fixed from one of its extremities to a fixed support and (S) is attached to the other extremity. (S) may slide without friction on a horizontal rail AB and its center of inertia G can move along a horizontal axis x'x.

At equilibrium, G coincides with the origin O of the axis x'x (Doc. 1).

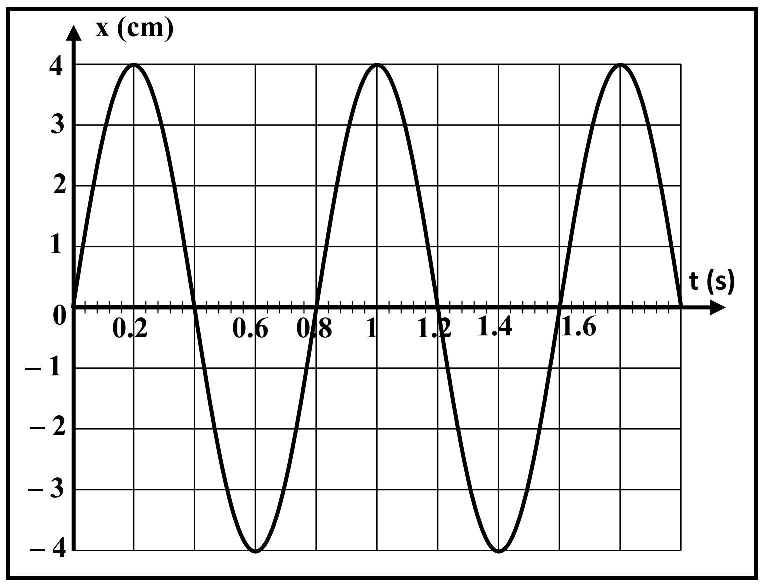


Doc. 1

At the instant $t_0 = 0$, G is at rest at O, (S) is launched with an initial velocity in the positive direction along x'x. Thus, (S) performs mechanical oscillations.

At an instant t, the abscissa of G is $x = \overline{OG}$ and the algebraic value of its velocity is $v = \frac{dx}{dt}$.

The horizontal plane passing through G is considered as the reference level for gravitational potential energy. Take $\pi^2 = 10$.



Doc. 2

1 – First method

A convenient apparatus is used to trace the curve of the abscissa x as a function of time (Doc. 2).

1-1) Referring to the graph of document 2, indicate:

1-1-1) the type of the oscillations of (S). Justify.

1-1-2) the value of the amplitude X_m of the oscillations;

1-1-3) the value of the proper period T_0 of the oscillations.

1-2) Indicate the nature of the motion of G and choose, from table below, the differential equation in x which describes the motion of G.

Equation 1	Equation 2	Equation 3
$x' + \frac{k}{m} x = 0$	$x'' + \frac{k}{m} x = 0$	$x'' + \frac{k}{m} x' = 0$

1-3) Determine the value of the stiffness k of the spring.

2 – Second method

2-1) The mechanical energy of the system [(S), spring, Earth] is conserved. Why?

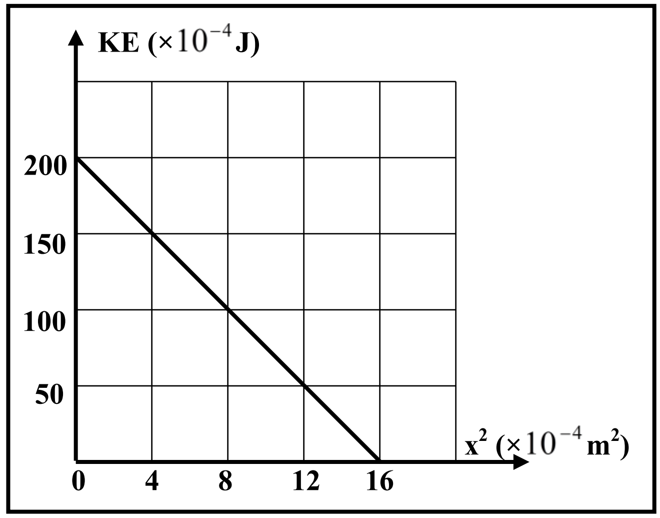
2-2) The expression of the kinetic energy of (S) can be written in the form: $KE = A - \frac{1}{2}k\,x^2$, where A is constant. What does A represent? Justify.

2-3) A convenient apparatus is used to trace the curve of the kinetic energy of (S) as a function of x^2 (Doc. 3). Using the graph of document 3, determine:

2-3-1) the value of A;

2-3-2) the value of the amplitude X_m of the oscillations;

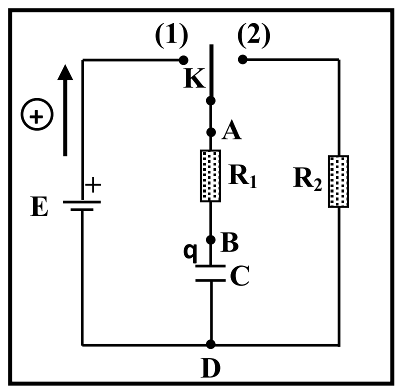
2-3-3) the value of the stiffness k.



Doc.3

<u>Exercise 2</u>: (7 points) **Charging and discharging of a capacitor**

The aim of this exercise is to determine the capacitance of a capacitor by two different methods.
Consider the circuit represented in document 1. It is formed of an ideal generator that maintains across its terminals a constant voltage of value E, a capacitor of capacitance C, two resistors of resistances $R_1 = 10\ k\Omega$, $R_2 = 20\ k\Omega$ and a double switch K.



Doc. 1

1 – Charging the capacitor

The capacitor is initially neutral. At the instant $t_0 = 0$, we put K in position (1); the charging phenomenon of the capacitor starts.

1-1) Theoretical study

1-1-1) Show that the differential equation that describes the variation of the voltage $u_C = u_{BD}$ across the capacitor has the form: $E = R_1 C \frac{du_C}{dt} + u_C$.

1-1-2) The solution of this differential equation has the form: $u_C = A(1 - e^{\frac{-t}{\tau_1}})$.
Determine the expressions of the constants A and τ_1 in terms of E, R_1 and C.

1-1-3) Deduce that $u_C = E$ at the end of charging of the capacitor.

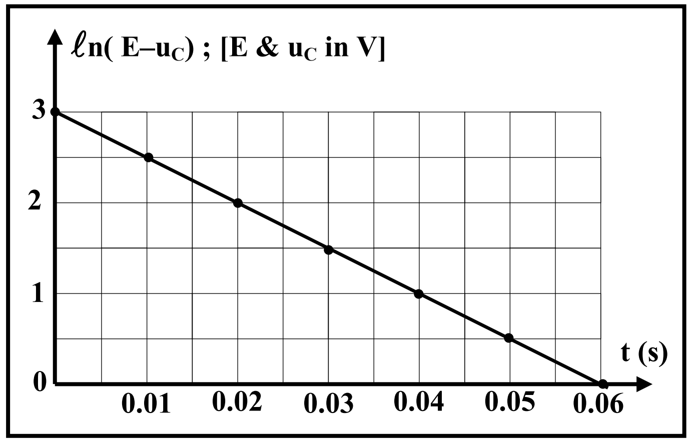
1-2) Experimental study

In order to determine the value of C, we use a convenient apparatus, which traces, during the charging of the capacitor, the curve representing $\ell n(E - u_C) = f(t)$ (Doc.2). [ℓn is the natural logarithm]

1-2-1) Determine, using the solution of the obtained differential equation, the expression of $\ell n\,(E - u_C)$ in terms of E, R_1, C and t.

1-2-2) Show that the shape of the curve in document 2 is in agreement with the obtained expression of $\ell n\,(E - u_C) = f(t)$.

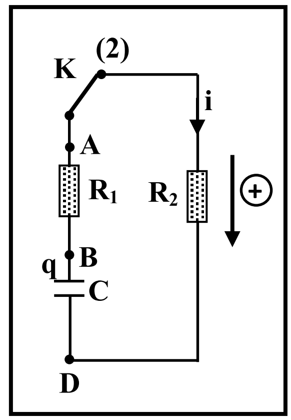
1-2-3) Using the curve of document 2, determine the values of E and C.



Doc. 2

2 – Discharging the capacitor

The capacitor being fully charged. At an instant taken as a new origin of time $t_0 = 0$, the switch K is placed at position (2); thus the phenomenon of discharging of the capacitor starts (Doc. 3).



Doc. 3

2-1) Theoretical study

2-1-1) Show that the differential equation in the voltage $u_C = u_{BD}$ across the capacitor has the form: $u_C + \alpha \dfrac{du_C}{dt} = 0$; where α is a constant to be determined in terms of R_1, R_2 and C.

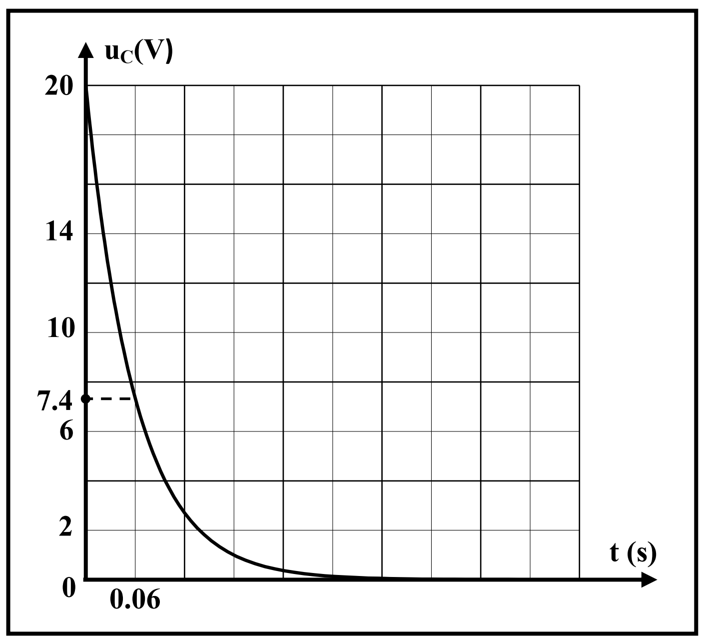
2-1-2) The solution of this differential equation has the form: $u_C = E\,e^{\frac{-t}{\tau_2}}$ where τ_2 is constant. Show that $\tau_2 = \alpha$.

2-2) Experimental study

The variation of the voltage u_C across the capacitor as a function of time is represented in document 4.

2-2-1) Determine, using document 4, the value of the time constant τ_2 of the discharging circuit.

2-2-2) Deduce the value of C.



Doc. 4

3 / 4

<u>Exercise 3</u> (7 points) **The radioactive isotope phosphorus 32**

The radioactive isotope phosphorus 32 ($^{32}_{15}P$) is used in the diagnosing of cancer. Phosphorus 32, is injected into the human body, it decays and gives radiations. These radiations are detected by an appropriate device to create the image of the inside of the human body.

The aim of this exercise is to determine the dose of radiation absorbed by a tissue of a patient during 6 days.

Phosphorus 32 ($^{32}_{15}P$) is a β^- emitter; it disintegrates to give an isotope $^{A}_{Z}S$ of sulfur.

Given:

- mass of $^{32}_{15}P$: 31.965 678 u;
- mass of $^{A}_{Z}S$: 31.963 293 u;
- mass of electron : 5.486×10^{-4} u ;
- The radioactive period of $^{32}_{15}P$: 14.3 days;
- 1 u = 931.5 MeV/c² ;
- 1 MeV = 1.6×10^{-13}J.

1 – Energy liberated by the decay of phosphorus 32

The disintegration of phosphorus 32 nucleus is given by the following reaction:

$$^{32}_{15}P \rightarrow {}^{A}_{Z}S + {}^{0}_{-1}e + {}^{0}_{0}\bar{\upsilon}$$

1-1) Determine A and Z.

1-2) Prove that the energy liberated by the above disintegration is E_{lib} = 1.7106 MeV.

1-3) The sulfur nucleus is produced in the ground state. The emitted antineutrino carries energy of 1.011 MeV.

1-3-1) The above disintegration of phosphorus 32 is not accompanied with the emission of gamma rays. Why?

1-3-2) Calculate the kinetic energy carried by the emitted electron knowing that phosphorus and sulfur are considered at rest.

2 – Absorbed dose

A patient is injected by a pharmaceutical product containing phosphorus 32. The initial activity of phosphorus 32 in the pharmaceutical product at $t_0 = 0$, is $A_0 = 1.36\times10^6$ Bq.

2-1) Calculate, in s^{-1}, the radioactive constant of phosphorus 32.

2-2) Deduce the number N_o of nuclei of phosphorus 32 present in the pharmaceutical product at $t_0 = 0$.

2-3)

2-3-1) Determine the remaining number N of nuclei of phosphorus 32 at t = 6 days.

2-3-2) Deduce the disintegrated number N_d of nuclei of phosphorus 32 during the 6 days.

2-3-3) The number of the emitted electrons is $N_{e^-} = 6.12\times10^{11}$ electrons during the 6 days. Why?

2-4) The emitted radiation is absorbed by a tissue of mass M = 112 g. The antineutrino does not interact with matter, and suppose that the energy of the emitted electrons is completely absorbed by the tissue.

2-4-1) Calculate the energy E_{abs} absorbed by the tissue during the 6 days.

2-4-2) The absorbed dose by the tissue is $D = \frac{E_{abs}}{M}$ during the 6 days. Deduce the value of D in J/kg.

Exercise 1: (6 points) **Mechanical oscillator**

Part			Solution	Mark
1	1-1	1-1-1	Free un-damped oscillation Since the amplitude is constant	0.25 0.25
		1-1-2	$X_m = 4$ cm.	0.5
		1-1-3	$T_0 = 0.8$ s.	0.5
	1-2		Nature simple harmonic motion or RSM Equation 2.	0.25 0.25
	1-3		The differential equation has the form : $x'' + \omega_0^2 x = 0$ $\omega_0 = \sqrt{\frac{K}{m}} = \frac{2\pi}{T_0}$; $\omega_0 = \frac{2\pi}{T_0} = 2.5\,\pi\ \mathrm{rad}/_{\mathrm{s}}$; $\omega_0 = \sqrt{\frac{K}{m}}$; $K = m \times \omega_0^2 = 25$ N/m	0.5 0.5
2	2-1		The mechanical energy of (S) is conserved due to the absence of friction **Or** : X_m = constant **Or:** The work done by the non conservative forces is zero.	0.25
	2-2		ME= KE + PE_e ; KE= ME - ½k $(x)^2$; A is mechanical energy	0.5 0.25
	2-3	2-3-1	For x = 0 ; KE = ME = A = 0.02 J	0.5
		2-3-2	KE = 0 ; x = X_m, from the graph $X_m^2 = 16\ \mathrm{cm}^2$, then $X_m = 4$ cm	0.75
		2-3-3	Slope = $\frac{KE_f - KE_i}{x_f^2 - x_i^2} = \frac{-200}{16} = -12.5\, J/m^2$; -12.5 = - ½ k , then k = 25 N/m **Or** : choose a point on the graph for x = X_m ; KE = 0J $X_m^2 = \frac{2A}{K}$, therefore k = 25 N/m	0.75

Exercise 2: (7 points) **Charging and discharging of a capacitor**

Partie			Solution	Note
1	1.1	1-1-1	$u_{AD} = u_{AB} + u_{BD}$, then $E = R_1 i + u_C$ with $i = C\frac{du_C}{dt}$ we get : $E = R_1 C\frac{du_C}{dt} + u_C$	0.5
		1-1-2	$\frac{du_C}{dt} = \frac{A}{\tau_1}e^{\frac{-t}{\tau_1}}$, replacing in the differential equation we get: $E = R_1 C\frac{A}{\tau_1}e^{\frac{-t}{\tau_1}} + A(1-e^{\frac{-t}{\tau_1}})$, then A = E and $\tau_1 = R_1 C$	0.25 0.5 0.5
		1-1-3	At the end of charging, $t\to\infty$, then $e^{\frac{-t}{\tau_1}} \to 0$, thus $u_C = E$ **<u>Or</u>** for t = 5τ ; uc = 0.99 E = E	0.5
	1-2	1-2-1	$u_C = E(1-e^{\frac{-t}{\tau_1}})$; $uc = E - Ee^{\frac{-t}{\tau_1}}$; $E - u_c = E\ e^{\frac{-t}{\tau_1}}$; $\ell n\,(E - u_C) = \ell n\,(E\ e^{\frac{-t}{\tau_1}})$ $\ell n\,(E - u_C) = \ell n\,E - \frac{t}{R_1 C}$	0.5
		1-2-2	$\ell n\,(E - u_C)$ has the form of y = at + b its slope a < 0 ; Is in agreement with the shape of the curve which is a straight line of negative slope not passing through the origin.	0.5
		1-2-3	The slope of this straight line is $-\frac{1}{R_1 C} = \frac{2.5-3}{0.01} = -50$, then $\frac{1}{R_1 C} = 50$ $C = 2\times10^{-6}$ F = 2 μF and $\ell n\,E = 3$, thus E = 20 V **<u>Or</u>** : For t = 0 , then $\ell n\,(E - u_C) = 3$; $3 = \ell n\,E$, thus E = 20 V For $\ell n\,(E - u_C) = 0$, so t = 0.06 s , thertefore $C = 2\times10^{-6}$ F	0.5 0.5
2	2.1	2-1-1	$u_C = (R_1 + R_2)\,i$ with $i = -C\frac{du_C}{dt}$, we get : $u_C + (R_1 + R_2)\ C\frac{du_C}{dt} = 0$. $u_C + \alpha\frac{du_C}{dt} = 0$, then $\alpha = (R_1 + R_2)\,C$.	1
		2-1-2	Replacing u_C by $u_C = E\,e^{\frac{-t}{\tau_2}}$ in the differential equation we get: $E\,e^{\frac{-t}{\tau_2}} + \alpha\,(-\frac{E}{\tau_2}e^{\frac{-t}{\tau_2}}) = 0$, therefore $\alpha = \tau_2$	0.25 0.5
	2.2	2.2-1	For uc = 7.4 V , then t = 0.06 s ; $7.4 = 20\,e^{\frac{-0,06}{\tau_2}}$, thus $\tau_2 = 0.0603$ s Or: From the graph at t = 0.06 s, $u_C = 7.4 = 0.37 \times 20$, so $\tau_2 = 0.06$ s.	0.5
		2.2-2	$\tau_2 = (R_1 + R_2)\,C$, then $C = 2\times10^{-6}$F = 2 μF	0.5

Exercise 3: (7 points) **The radioactive isotope phosphore 32**

Part			Solution	Mark
1	1-1		$^{32}_{15}P \rightarrow ^{A}_{Z}S + ^{0}_{-1}e + ^{0}_{0}\bar{\nu}$. By applying Soddy's laws: 32= A + 0 + 0 , Then A = 32; 15 = Z – 1 + 0 , then Z = 16.	0.25 0.5
	1-2		$\Delta m = m_{before} - m_{after} = 31.965678 - (31.963293 + 5.486 \times 10^{-4}) = 1.8364 \times 10^{-3}$ u $\Delta m = 1.8364 \times 10^{-3} \times 931.5$ MeV/c$^2 \cong 1.706$ MeV/c^2. $E_{lib} = \Delta m \cdot c^2 = 1.711 \frac{Mev}{c^2} \cdot c^2$, then $E_{lib} = 1.706$ MeV	0.5 0.75
	1-3	1-3-1	Gamma rays are not emitted in the above decay since the daughter nucleus (sulfur) is produced in the ground state.	0.25
		1-3-2	$E_{lib} = KE_{\beta^-} + E_{\nu^-}$, so $1.7106 = KE_{\beta^-} + 1.011$, therefore $KE_{\beta^-} = 0.6996$ MeV.	0.5
2	2-1		$\lambda = \frac{\ell n\, 2}{T} = \frac{\ell n\, 2}{14.3 \times 24 \times 3600}$, therefore $\lambda = 5.61 \times 10^{-7} s^{-1}$	0.75
	2-2		$A_o = \lambda N_o$, $N_o = \frac{1.36 \times 10^6}{5.61 \times 10^{-7}}$, therefore $N_o = 2.424 \times 10^{12}$ nuclei	0.75
	2-3	2-3-1	$n = \frac{t}{T} = \frac{6}{14.3} = 0.4195$, $N = \frac{N_o}{2^n} = \frac{2.424 \times 10^{12}}{2^{0.4195}}$, therefore $N = 1.812 \times 10^{12}$ nuclei	1
		2-3-2	$N_d = N_o - N = 2.424 \times 10^{12} - 1.812 \times 10^{12}$, therefore $N_d = 6.12 \times 10^{11}$ nuclei	0.5
		2-3-3	One electron is emitted in one decay of phosphorous-32, so $N_{e^-} = N_{decay}$ Therefore, $N_{e^-} = 6.12 \times 10^{11}$	0.25
	2-4	2-4-1	$E_{absorb} = N_{decay} \times KE_{\beta^-} = 6.12 \times 10^{11} \times 0.6996 \times 1.6 \times 10^{-13}$ J So $E_{absorb} = 6.8504 \times 10^{-2}$ J	0.5
		2-4-2	$D = \frac{E_{absorb}}{m} = \frac{6.8504 \times 10^{-2}}{0.112}$, therefore D = 0.611 Gy = 0.611 J/kg.	0.5

This exam is formed of three obligatory exercises in 3 pages.
The use of non-programmable calculator is recommended

Exercise 1 (6.5 points)

Determination of the capacitance of a capacitor

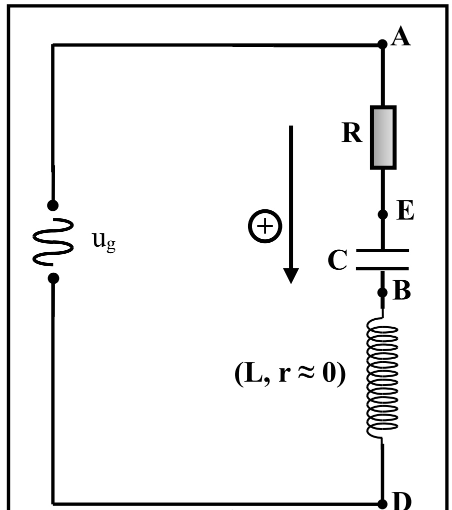
The aim of this exercise is to determine the capacitance C of a capacitor. For this aim, consider the electric circuit shown in document 1. The circuit includes a resistor of resistance R, a coil of inductance L and of negligible resistance r, a capacitor of capacitance C, and a low frequency generator (LFG) delivering alternating sinusoidal voltage:

$u_g = u_{AD} = U_m \cos(\omega t)$ (u in V ; t in s).

An oscilloscope is connected so as to visualize, as a function of time, the variation of the voltage u_{AD} across the generator on channel Y_1 and the voltage $u_{BD} = u_{coil}$ across the coil on channel Y_2 (Document 2).

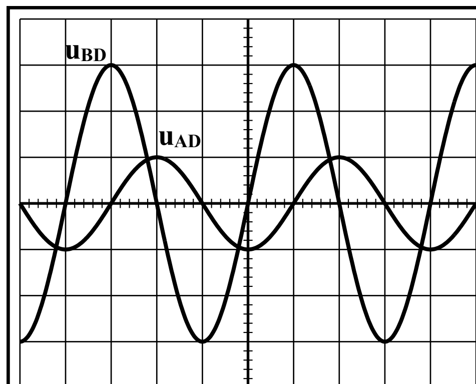
The vertical sensitivity of channel 1 is: $Sv_1 = 5$ V/div.

The vertical sensitivity of channel 2 is: $Sv_2 = 2$ V/div.



Doc. 1

1) Redraw the circuit of document 1 showing on it the connections of the oscilloscope.
2) Using the waveforms of document 2, determine:
   2-1) the amplitudes U_m and $U_{m(coil)}$ of the voltages u_g and u_{coil}.
   2-2) the phase difference between the two voltages.



Doc.2

3) Write the expression of the voltage u_{coil} across the coil as function of time t and the angular frequency ω.
4) The expression of the current i in the circuit is:
   $i = \dfrac{9.375\,\pi}{\omega}\cos(\omega t)$ (i in A ; t in s).
   Determine the expression of the voltage u_{coil} across the terminals of the coil in terms of L, ω and t.
5) Using the results of part 3 and 4, show that L = 0.204 H.
6) Indicate the value of the phase difference between u_g and i.
7) A phenomenon takes place in the circuit. Name this phenomenon.
8) Deduce the value of C knowing that the angular frequency $\omega = 300\pi$ rad/s.

Exercise 2 (6.5 points)

Ionization and fission of uranium

The aim of this exercise is to study the ionization and the fission of a uranium isotope.

Given:

1 eV = 1.6×10^{-19} J ; speed of light in vacuum: c = 3×10^{8} m/s ; Planck's constant: h = 6.6×10^{-34} J.s.

Mass of ${}^{235}_{92}U$ nucleus = 234.99342 u ; 1u = 1.66 $\times10^{-27}$ kg.

1- Ionizing one of the uranium isotopes

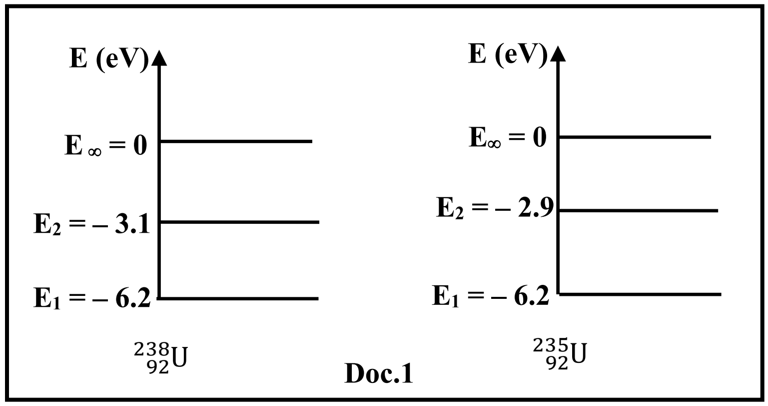
A monochromatic radiation of frequency $\nu = 8\times10^{14}$ Hz illuminates a sample of uranium containing the isotopes ${}^{235}_{92}U$ and ${}^{238}_{92}U$.

1-1) Calculate, in Joules and in eV, the energy of a photon of the incident radiation.

1-2) Document 1 shows some of the energy levels of the isotopes ${}^{235}_{92}U$ and ${}^{238}_{92}U$.

The photons of the incident radiation can excite one of these isotopes of uranium from energy level E_1 to energy level E_2.

Specify which of the two isotopes will be excited.



Doc.1

1-3) Before it de-excites, the excited isotope receives another photon of same frequency ν.

1-3-1) Show that this isotope will be ionized.

1-3-2) Determine the maximum kinetic energy KE_{max} of the liberated electron.

1-4) This experiment shows evidence of one of the two aspects of light. Name this aspect.

2- Nuclear reaction

The isotope of uranium which undergoes fission in the nuclear power plant is uranium-235.

One of the fission reactions of uranium-235 nucleus is given by:

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{90}_{36}Kr + {}^{X}_{56}Ba + 8\,{}^{1}_{0}n + \gamma$$

2-1) This reaction is provoked. Why?

2-2) What condition must the projectile satisfy in order to realize this reaction?

2-3) Use one of the conservation laws to calculate x.

2-4) The energy liberated by the fission of each nucleus of uranium-235 is about 200 MeV. In what forms does this energy appear?

2-5) A nuclear power plant of efficiency 40 % furnishes an electric power 600 MW. Determine, in kg, the mass of uranium-235 consumed in 1 day in this power plant.

Exercise 3 (7 points)

Determination of the mass of a block and the stiffness of a spring

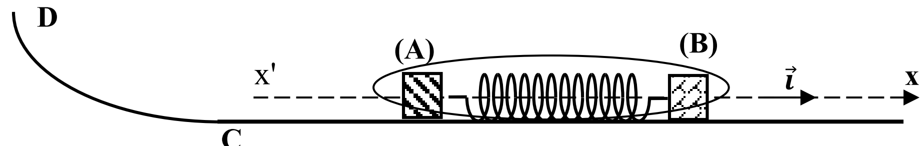
Consider two blocks, (A) of unknown mass m_A and (B) of mass m_B = 0.8 kg, and a spring (R) of negligible mass and of stiffness k. The aim of this exercise is to determine m_A and k.

Neglect all the forces of friction and take g = 10 m/s^2.

1- First experiment: Determination of m_A

The spring is placed on a horizontal track. The spring is compressed between (A) and (B) by means of a light string (Document 1).

The center of mass of (A) and that of (B) belong to the same horizontal plane which is taken as a reference level for gravitational potential energy.
The x-axis extends positively to the right.
We burn the string, (A) and (B) are ejected in opposite directions.



Doc. 1

1-1) Name the external forces acting on the system [(A), (B) and (R)].

1-2) Deduce that the linear momentum of the system [(A), (B) and (R)] is conserved during the motion of (A) and (B) on the horizontal track.

1-3) The velocity of the center of mass of block (B) just after ejection is $\vec{V}_B = 0.75\,\vec{i}$ (m/s).

1-3-1) Determine the linear momentum $\vec{P}_A$ of block (A).

1-3-2) Deduce in terms of m_A the velocity $\vec{V}_A$ of the center of mass of (A) just after ejection.

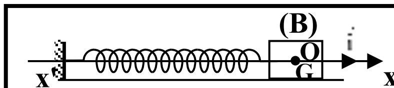
1-4) Block (A) continues its motion and reaches a curvilinear path CD situated in the vertical plane (Document 1). The maximum height attained by the center of mass of (A) above the reference level is $h_{max} = 5$ cm.

1-4-1) Apply the principle of conservation of mechanical energy to the system [(A), Earth] to determine the magnitude V_A of $\vec{V}_A$.

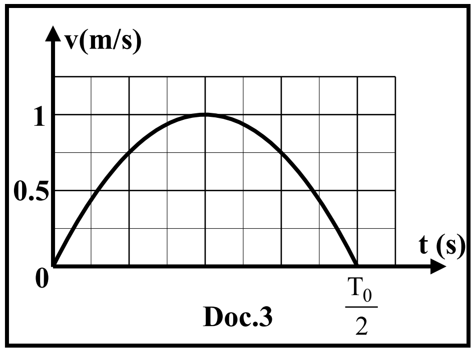
1-4-2) Deduce the value of the mass m_A.

2- Second experiment: Determination of k

We fix block (B) to one of the ends of the spring (R), the other end of the spring is attached to a fixed support (Document 2).
At equilibrium, (B) is at O taken as an origin of abscissa of the axis x'x.
(B) is displaced, from point O along the axis x'x by a distance X_m in the negative direction, and then it is released without initial velociy at the instant $t_0 = 0$. At an instant t, the abscissa of the center of mass G of (B) is x and the algebraic measure of its velocity is v.

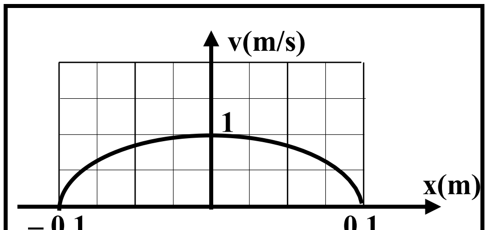


Doc.2



Doc.3

During the motion of (B) between $t_0 = 0$ and $t = \frac{T_0}{2}$ [T_0 is the proper period of the oscillations of (B)], an appropriate system traces the graphs of documents (3) and (4).
Document (3): represents the variation of the speed of G as a function of time.
Document (4): represents the variation of the speed of G as a function of the abscissa x.



Doc.4

2-1) Determine, by referring to document (3), the value of the maximum kinetic energy of (B).

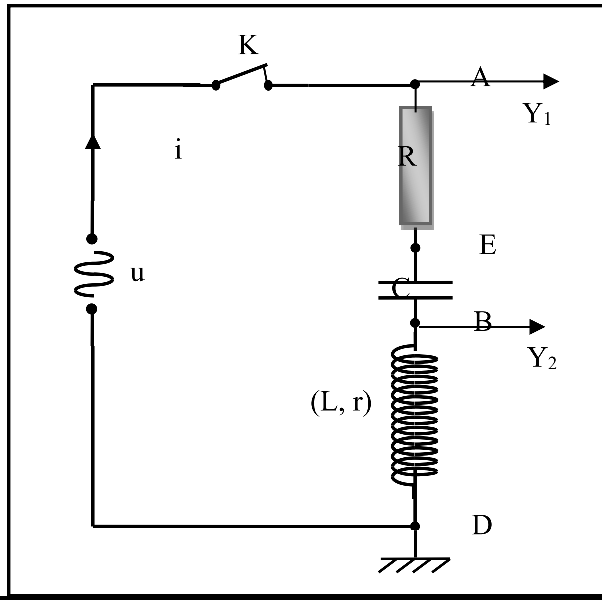
2-2) Deduce the value of the maximum elastic potential energy of the system [(R), (B), Earth].

2-3) Indicate, by referring to document (4), the value of X_m.

2-4) Deduce the value of k.

مسابقة في مادة الفيزياء
المدة: ساعتان

الاسم:
الرقم:

<table>
<tr><th colspan="4">Exercise 1 : Determination the capacitance of a capacitor</th></tr>
<tr><th>Question</th><th colspan="2">Answer</th><th>mark</th></tr>
<tr><td>1</td><td colspan="2">
</td><td>0.5</td></tr>
<tr><td rowspan="2">2</td><td>2-1</td><td>$U_{\max(g)} = y \times Sv_1 = 5V$
$U_{\max(l)} = y \times Sv_2 = 6V$</td><td>0.5
0.5</td></tr>
<tr><td>2-2</td><td>$\Delta\emptyset = \frac{2\pi d}{D} = \frac{\pi}{2} rad.$</td><td>0.5</td></tr>
<tr><td>3</td><td colspan="2">$u_{coil} = 6\cos(\omega t + \frac{\pi}{2})$ = - 6 sin (ωt)</td><td>0.75</td></tr>
<tr><td>4</td><td colspan="2">$u_{coil} = L\frac{di}{dt} = -L \times 9.375\pi \sin(\omega t)$.</td><td>1</td></tr>
<tr><td>5</td><td colspan="2">$u_{coil} = u_{coil}$, then $6 = L \times 9.375\pi$; then L = 0.204 H.</td><td>1</td></tr>
<tr><td>6</td><td colspan="2">zero</td><td>0.5</td></tr>
<tr><td>7</td><td colspan="2">Current resonance</td><td>0.5</td></tr>
<tr><td>8</td><td colspan="2">Current resonance, $LC(\omega)^2 = 1$, $C = 5.518\ \mu F$.</td><td>0.75</td></tr>
</table>

Exercise 2 : Ionization and fission of uranium				
Question			**Answer**	**mark**
1	1		$E = h\nu$ $E = 6.6\times10^{-34}\times8\times10^{14} = 5.28\times10^{-19}$ J $E = 3.3$ eV	**0.25** **0.5** **0.25**
	2		$E = 3{,}3$ eV $= E_2 - E_1$ for ${}^{235}_{92}U$ ${}^{235}_{92}U$ can be excited	**0.5** **0.25**
	3	1	$E_{ionisation} = E_\infty - E_2 = 2{,}9$ eV $E_{photon} > 2.9$ eV, the isotope can be ionized	**0.25** **0.5**
		2	$E_{photon} = (E_\infty - E_2) + K.E_{max} = E_{ionisation} + K.E_{max}$ $K.E_{max} = 0.4$ eV	**0.5** **0.5**
	4		Aspect corpuscular of light	**0.25**
2	1		Since it has an external intervention (bombarded by a neutron)	**0.25**
	2		Thermal neutron **<u>or</u>** slow neutron **<u>or</u>** KE ≈ 0.025 eV	**0.25**
	3		Law of conservation of mass number: x = 138	**0.5**
	4		Kinetic energy of emitted nuclei, KE of emitted particles, energy of photons γ	**0.5**
	5		$E_{elect} = P\times t = 600\times10^6\times24\times3600 = 5.184\times10^{13}$ J efficiency $= \dfrac{E_{'electrique}}{E_{nucléaire}}$; $E_{nuclear} = E_{elect}\dfrac{100}{40} = 1.296\times10^{14}$ J $m({}^{235}_{92}U) = 234.99342$ u $= 234.99342\times1{,}66\times10^{-27}$ kg $= 3.90\times10^{-25}$ kg 200 MeV $= 200\times1{,}6\times10^{-13}$ J $= 3.20\times10^{-11}$ J $m_{totale} = \dfrac{1.296\times10^{14}\times3.90\times10^{-25}}{3.20\times10^{-11}} = 1.58$ kg	**1.25**

Exercise 3 : Determination of the mass of a block and the stiffness of a spring				
Question			**Answer**	**Mark**
1	**1-1**		Weight $m_A\vec{g}$ of (A), normal reaction $\vec{N}_A$ on (A), Weight $m_B\vec{g}$ de (B), normal reaction $\vec{N}_B$ on (B).	**0.5**
	1-2		$\Sigma\vec{F}_{ext} = \frac{d\vec{P}}{dt}$, then $m_A\vec{g} + \vec{N}_A + m_B\vec{g} + \vec{N}_B = \vec{0} = \frac{d\vec{P}}{dt}$, The linear momentum of the system (A, B, spring) is conserved.	**0.75**
	3	**1**	$\vec{P}_{initial} = \vec{P}_{final}$, then $\vec{0} = \vec{P}_A + \vec{P}_B$, $\vec{P}_A = -\vec{P}_B$ $\vec{P}_A = -m_B\vec{V}_B = -0.8 \times 0.75\,\vec{\imath} = -0.6\,\vec{\imath}$ (kg.m/s)	**1**
		2	$\vec{P}_A = m_A\vec{V}_A$, $\vec{V}_A = -\frac{0.6}{m_A}\vec{\imath}$ (m/s).	**0.5**
	4	**1**	Let F the maximum point reached by (A) $ME_1 = ME_2$, $\frac{1}{2} m_A V_A^2 + m_A g h_A = \cancel{\frac{1}{2} m_A} V_F^2 \cancel{+ m_A} g h_{max}$ $\frac{1}{2} m_A V_A^2 = m_A g h_{max}$, $V_A = \sqrt{2 \times g \times h_{max}} = \sqrt{2 \times 10 \times 0.05} = 1$ m/s	**1.25**
		2	$V_A = \frac{0.6}{m_A} = 1$, then $m_A = 0.6$ kg.	**0.5**
2	**2-1**		Graphically $V_{max} = 1$m/s $KE_{max} = ½\, m_B V_{max}^2 = 0.4$ J	**0.75**
	2-2		The mechanical energy of the system is conserved: $PE_{max} = KE_{max} = 0.4$ J	**0.5**
	2-3		$X_{max} = 10$ cm	**0.5**
	2-4		$½\, k X_{max}^2 = 0.4$ then $k = 80$ N/m	**0.75**

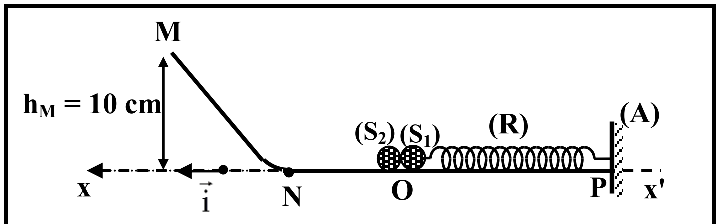
This exam is formed of three exercises in three pages
The use of non- programmable calculators is recommended

Exercise 1 (7 points)

Determination of the stiffness of a spring

In order to determine the stiffness k of a massless spring (R), we consider:

- a track MNP found in a vertical plane ;
- a massless spring (R) of horizontal axis and stiffness k, having one end fixed to a support (A); the other end is connected to an object (S_1) considered as a particle of mass $m_1 = 0.2$ kg;
- an object (S_2) considered as a particle of mass $m_2 = 0.3$ kg, placed at the origin O of a horizontal x-axis of unit vector $\vec{i}$ (Doc. 1).



Doc. 1

Neglect all the forces of friction.

Take:

- the horizontal plane passing through NP as a reference level for gravitational potential energy;
- $g = 10$ m/s^2.

1- Collision between (S_1) and (S_2)

At equilibrium, (S_1) coincides with O. (S_1) is shifted from O to the right by a certain distance and it is released from rest. (S_1) reaches O with a velocity $\vec{V_1} = 2\,\vec{i}$ (m/s), and enters into a head-on collision with (S_2) initially at rest. Just after collision, (S_1) rebounds with a velocity $\vec{V_1'} = -0.4\,\vec{i}$ (m/s) and (S_2) moves to the left with a velocity $\vec{V_2'} = V_2'\,\vec{i}$.

1-1) Applying the principle of conservation of linear momentum for the system [(S_1), (S_2)], show that $V_2' = 1.6$ m/s.

1-2) Specify whether this collision is elastic or not.

2- Motion of (S_2) after collision

Just after collision, (S_2) moves along the horizontal track PN with the speed V_2' and then continues its motion along the inclined plane MN. (S_2) leaves the inclined plane at M with a speed V_M. The height of M above the reference level is $h_M = 10$ cm. Determine the speed V_M of (S_2) at point M.

3- Oscillation of (S_1)

After collision, (S_1) oscillates along the x-axis. At an instant t, the abscissa of (S_1) is x and the algebraic value of its velocity is $v = \frac{dx}{dt}$.

3-1) Write, at an instant t, the expression of the mechanical energy of the system [(S_1), spring, Earth] in terms of m_1, k, x and v.

3-2) Derive the second order differential equation in x that describes the motion of (S_1).

3-3) Deduce the expression of the proper period T_0.

3-4) Calculate k knowing that $T_0 = 0.314$ s.

Exercise 2 (6 points)

Scintigraphy in medicine

The bones scintigraphy is a medical examination that permits to observe bones and articulations. The aim of this exercise is to study a radioactive sample used in this scintigraphy.
This medical examination uses technetium-99 produced due to the disintegration of molybdenum-99 according to the following nuclear reaction:

$$^{99}_{42}Mo \rightarrow \, ^{99}_{43}Tc \; + \; ^{A}_{Z}X \; + \; \gamma$$

The energy of the emitted gamma (γ) photon is 140 keV.

Given: $c = 3\times10^{8}$ m.s^{-1}; 1eV = 1.6×10^{-19} J; Planck's constant $h = 6.6\times10^{-34}$ J.s.

1- Identify the emitted particle $^{A}_{Z}X$, indicating the used laws.

2- The emitted particle $^{A}_{Z}X$ is always accompanied with the emission of another particle. Name this particle.

3- Indicate the cause of the emission of the gamma photon.

4- Calculate the wavelength of the emitted gamma photon.

5- Technetium-99 is a radioactive substance.
The graph of document 2 represents the activity of a sample of technetium-99 as a function of time.
Using document 2, show that the radioactive period (half-life) of technetium-99 is T = 6 hrs.

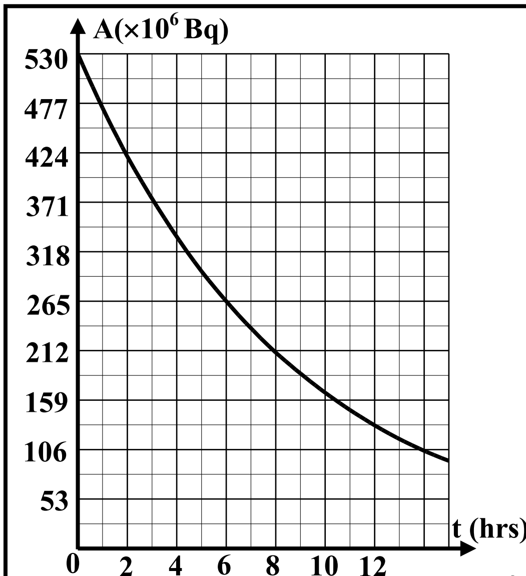
6- In a session of scintigraphy examination, a patient is injected at $t_0 = 0$ by techenetium-99 of activity $A_0 = 530 \times10^{6}$ Bq. At the end of the examination session, the activity of technetium in the body of the patient is 63% of its initial value.

6-1) Write, at instant t, the expression of the activity A in terms of A_0, t and the decay constant λ.

6-2) Using the preceded expression, determine:

6-2-1) the duration of the examination session;

6-2-2) the ratio $\frac{A}{A_0}$ of technetium-99 at t = 40 hrs.



Doc. 2

Exercise 3 (7 points)

RLC series circuit in the radio

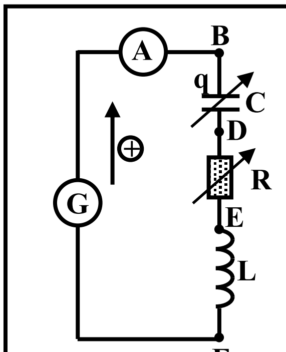
One of the useful applications of an RLC series circuit is used in radios.
This exercise studies the effect of the capacitance C on the detection of the radio wave and the effect of the resistance R on the loudness of the sound emitted by the radio.

1 – Experimental study of an RLC series circuit

Document 3 represents an RLC series circuit formed of:

- a capacitor of adjustable capacitance C;
- a resistor of adjustable resistance R;
- a coil of inductance L = 0.317 H and negligible resistance;
- an ammeter (A) of negligible resistance.

This circuit is connected across a generator (G) maintains across its terminals an



Doc. 3

alternating sinusoidal voltage $u_G = u_{BF} = 3\sin(\omega t)$, ($u_G$ in V, t in s) and $\omega = 314$ rad/s.
The expression of the current in the circuit is $i = I_m \sin(\omega t + \varphi)$.
For each value of C, the ammeter permits to obtain the amplitude I_m of the current i.
The graph of document 4 represents I_m as a function of C.

1-1) Indicate the value C_0 of C at which I_m attains a maximum value.

1-2) Calculate the value of $LC_0\omega^2$.

1-3) Name then the electric phenomenon observed on document 4.

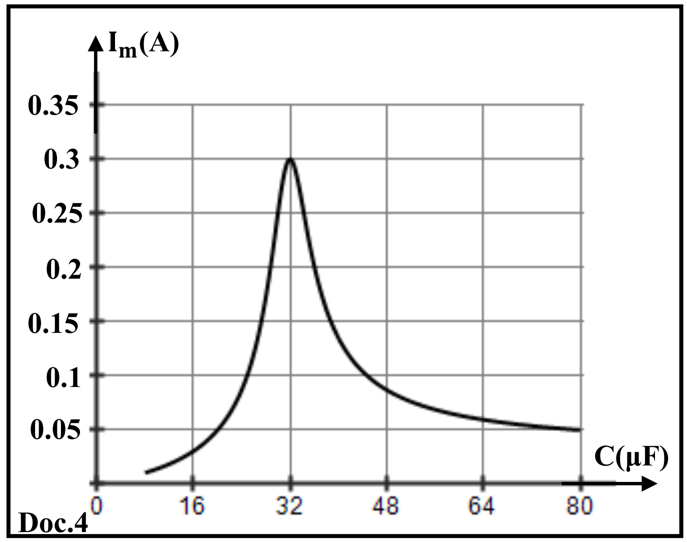
1-4) The capacitance of the capacitor is C = 32 μF.

1-4-1) Pick out graphically the value of I_m.

1-4-2) Show that the expression of the current is given by:
$i = 0.3\sin(314\,t)$, (i in A, t in s).

1-4-3) Determine the expression of the voltage $u_L = u_{EF}$ across the terminals of the coil as a function of time t.

1-4-4) Determine the expression of the voltage $u_C = u_{BD}$ across the terminals of the capacitor as a function of time t.



Doc.4

1-4-5) Show that $u_R \sqcup u_G = 3\sin(314t)$, using the law of addition of voltages $u_G = u_C + u_L + u_R$ where $u_R = u_{DE}$ is the voltage across the resistor.

1-4-6) Deduce the value of R.

1-4-7) We decrease the value of R to 2 Ω. Calculate the new value of the maximum current in the circuit using the relation $u_R = u_G$.

2 - RLC series circuit in the radio

Each radio station broadcasts an electromagnetic wave (radio wave) of precise frequency f.
When this radio wave of frequency f is received by the antenna of a radio, it is converted into electric sinusoidal signal of same frequency f; thus the antenna plays the role of a generator and feeds the RLC series circuit in the radio.
Given:

- the inductance of an RLC series circuit in a radio is L = 0.2 mH;
- the values of R and C can be adjusted;
- when the circuit enters an electric phenomenon similar to that of part (1-3) the antenna receives the desired frequency of the wave of the broadcast.

2-1) Determine the value of C so that the antenna receives a radio wave of desired frequency 1000 kHz.

2-2) To increase the intensity of the emitted sound by the radio we have to increase the value of the current in the circuit. Indicate whether we have to increase or decrease the resistance R in order to increase the intensity of the emitted sound by the radio.

أسس التصحيح – مادة الفيزياء

Exercise 1 : (7 points) Determination of stiffness			
Part		**Answer**	**Mark**
1	**1-1**	$\vec{P}_{\text{just before}} = \vec{P}_{\text{just after}}$ $m_1\vec{V}_1 + \vec{0} = m_1\vec{V'}_1 + m_2\vec{V'}_2$ $0.2 \times 2\,\vec{i} = 0.2 \times (-\,0.4)\,\vec{i} + 0.3\vec{V'}_2$ $0.48\,\vec{i} = 0.3\,\vec{V'}_2$; $\vec{V'}_2 = 1.6\,\vec{i}$, then $V'_2 = 1.6$ m/s	**1.25**
	1-2	$KE_{before} = \frac{1}{2}\, m_1 V_1^2 = \frac{1}{2}\,(0.2) \times (2)^2 = 0.4$ J $KE_{after} = \frac{1}{2}\, m_1 V'^2_1 + \frac{1}{2}\, m_2 V'^2_2 = \frac{1}{2}\,(0.2) \times (0.4)^2 + \frac{1}{2}\,(0.3) \times (1.6)^2 = 0.4$ J $KE_{before} = KE_{after}$, then the collision is elastic	**0.5** **0.5** **0.5**
2		$ME_{(O)} = ME_{(M)}$ (forces of friction are neglected) $KE_{(O)} + PE_{g\,(O)} = KE_{(M)} + PE_{g\,(M)}$ $\frac{1}{2}\,(0.3) \times (1.6)^2 + 0 = 0.3 \times 10 \times 0.1 + \frac{1}{2}\,(0.3)\, V_M^2$ $0.348 = 0.3 + 0.15\, V_M^2$ $V_M^2 = 0.56$, then $V_M = 0.748$ m/s	**0.5** **0.5** **0.5**
3	**3-1**	$ME = KE + PE_g + PE_{el} = \frac{1}{2}\, m_1\, v^2 + \frac{1}{2}\, k\, x^2$	**0.5**
	3-2	No friction : ME = constant, then $\frac{dME}{dt} = 0$ $\frac{1}{2}\, m_1\, 2vv' + \frac{1}{2}\, k\, 2xx' = 0$; ($v = x' \neq 0$, $v' = x''$), then $m_1x'' + kx = 0$ $x'' + \frac{k}{m_1}\, x = 0$	**1**
	3-3	The differential equation has the form $x'' + \omega_0^2\, x = 0$ $\omega_0^2 = \frac{k}{m_1}$ and $T_0 = \frac{2\pi}{\omega_0} = 2\pi\sqrt{\frac{m_1}{k}}$	**0.25** **0.5**
	3-4	$T_0 = 0.314$ and $T_0 = 2\pi\sqrt{\frac{m_1}{k}}$ $0.314 = 2 \times 3.14\sqrt{\frac{0.2}{k}}$ then $k = 80$ N/m	**0.5**

Exercise 2: (6 points)	**Scintigraphy in medicine**	
Part	**Answer**	**Mark**
1	According to the laws of conservation of mass number and charge number : A = 0 and Z = -1 Then, ${}_{Z}^{A}X$ is an electron of symbol ${}_{-1}^{0}e$	**0.75** **0.5**
2	Antineutrino	**0.5**
3	The de-excitation of the daughter nucleus ″Technetium″	**0.5**
4	$E = h\,\frac{c}{\lambda}$, $\lambda = \frac{hc}{E}$, then $\lambda = 8.839\times10^{-12}$ m	**0.75**
5	At $t_0 = 0$; $A_0 = 530\times10^{6}$ Bq At t = T : $A = \frac{A_0}{2} = 265\times10^{6}$ Bq Therefore, t = T = 6 hrs (from graph)	**0.5**
6 **6-1**	$A = A_0\, e^{-\lambda t}$	**0.5**
6 **6-2** **6-2-1**	$0.63\, A_0 = A_0\, e^{-\lambda t}$; $\ln 0.63 = -\lambda\times t$ $0.46 = \lambda\, t$ but $\lambda = \frac{\ln 2}{T} = 0.115$ hr $^{-1}$ Then, $t = \frac{0.46}{\lambda} = 4$ hrs	**1**
6 **6-2** **6-2-2**	$\frac{A}{A_0} = e^{-\lambda t} = e^{-0.115\times40} = 0.01 = 1$ %	**1**

Exercise 3: (7 points) RLC series circuit

Part			Answer	Mark
1	1-1		$C_0 = 32\ \mu F$	0.25
	1-2		$LC_0\omega^2 = 0.317 \times 32 \times 10^{-6} \times (314)^2 = 1$	0.5
	1-3		Current resonance	0.5
	1-4	1	$I_m = 0.3$ A	0.25
		2	$i = I_m \sin(\omega t + \varphi) = 0.3 \sin(314\ t)$, since $I_m = 0.3$ A and in case of current resonance $\varphi = 0$	0.5
		3	$u_L = L\dfrac{di}{dt} = L \times 0.3 \times 314 \times \cos(314\ t) = 29.86 \cos(314\ t)$	0.75
		4	$u_C = u_{BD} = \dfrac{q}{C}$ $i = \dfrac{dq}{dt} = C\dfrac{du_C}{dt}$; $du_C = \dfrac{i}{C}dt$ Then : $u_C = \dfrac{0.3}{32 \times 10^{-6}} \int \sin(314\ t)\,dt$ $u_C = \dfrac{-0.3}{32 \times 10^{-6} \times 314} \cos(314\ t) = -29.656 \cos(314\ t)$	1
		5	$u_G = u_C + u_L + u_R$ but $u_C \cong -u_L$ then $u_C + u_L = 0$ then $u_G \cong u_R = 3 \sin(314\ t)$	0.75
		6	$U_{Rm} = 3 = R\, I_m$, then $R = \dfrac{3}{0.3} = 10\ \Omega$	1
		7	$U_{Rm} = 3 = R\, I'_m$, then $I'_m = \dfrac{3}{2} = 1.5$ A	0.5
2	2-1		Current resonance: $f^2 = \dfrac{1}{4\pi^2 LC}$ Then $C = \dfrac{1}{4\pi^2 L f^2} = 1.267 \times 10^{-10}$ F $= 0.126$ nF	0.75
	2-2		R should be decreased	0.25

وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانـاتالرسميّة	امتحانات الشهادة الثانوية العامة الفرع: علوم الحياة	دورة الـعام 2018 الاستثنائيّة السبت فـي 4 آب 2018
	مسابقة في مادة الفيزياء المدة: ساعتان	الاسم: الرقم:

This exam is formed of three obligatory exercises in 3 pages.

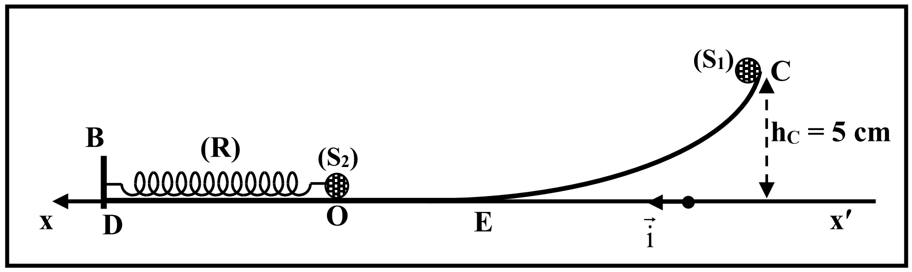
The use of non-programmable calculator is recommended

Exercise 1 (7points)

Determination of the stiffness of a spring

In order to determine the stiffness k of a spring (R), we consider:

- a track CEOD, situated in a vertical plane, formed of a curved part CE and a horizontal part EOD ;
- a horizontal spring (R)of negligible mass and stiffness k;
- two identical objects (S_1) and (S_2) considered as particlesand of same mass m.



Doc .1

We fix the spring (R) from one of its ends to a support B; whereas the other end is connected to the object (S_2).

At equilibrium, (S_2) coincides with the origin O of a horizontal x-axis of unit vector $\vec{i}$.

We release (S_1) without initial speed from point C situated at a height h_C = 5 cm above the x-axis as shown in document 1.

Neglect all the forces of friction.

Take:

- the horizontal plane containing the x-axis as a reference level for gravitational potential energy;
- $g = 10\ m/s^2$ and $\pi = 3.14$.

1. (S_1) reaches (S_2) with a velocity $\vec{V_1} = V_1\,\vec{i}$. Apply the principle of conservation of mechanical energy of the system [(S_1) – Earth] to determine the magnitude V_1 of $\vec{V_1}$.

2. (S_1) enters into a head on elastic collision with (S_2) which is initially at rest. Verify that, just after this collision,(S_1) becomes at rest and (S_2) moves with a speed V_0 = 1 m/s.

3. Just after the collision, (S_2) oscillates along the x-axis. The instant of the collision at point O is taken as an initial time $t_0 = 0$.

At an instant t, the abscissa of (S_2) is x and the algebraic value of its velocity is $v = \frac{dx}{dt}$.

3.1) Establish the second order differential equation in x that describes the motion of (S_2).

3.2) The solution of the obtained differential equation is $x = A\sin(\frac{2\pi}{T_0}t)$, where A is constant and T_0 is the proper period of the oscillation of (S_2).

3.2.1) Determine the expression of T_0 in terms of m and k.

3.2.2) Determine the expression of A in terms of V_0 and T_0.

3.2.3) The constant A is a characteristic of the oscillatory motion of (S_2). Name this characteristic.

4. At an instant t_1 = 314ms, (S_2)returns back to point O for the first time. Deduce the value of T_0.

5. Calculate the value of A.

6. Determine by two different methods the value of k, knowing that m = 400 g.

Exercise 2 (7 points)

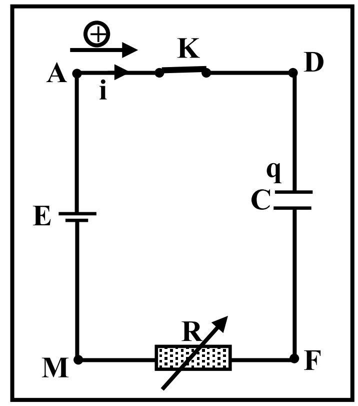
Effect of the resistance on the charging of a capacitor

The aim of this exercise is to study the effect of the resistance of a resistor on the charging of a capacitor.

For this aim, we set-up the circuit of document 2that includes:

- A capacitor, initially uncharged, of capacitance C = 4 μF;
- a resistor of adjustable resistance R;
- an ideal battery of voltage $u_{AM} = E$;
- a switch K.

We close the switch at $t_0 = 0$, and the charging process starts.



Doc. 2

1. Theoretical study

1.1) Derive the differential equation that describes the variation of the voltage$u_{DF} = u_C$ during the charging of the capacitor.

1.2) The solution of this differential equation has the form of: $u_C = A + B\,e^{Dt}$. Determine the constants A, B and D in terms of E, R and C.

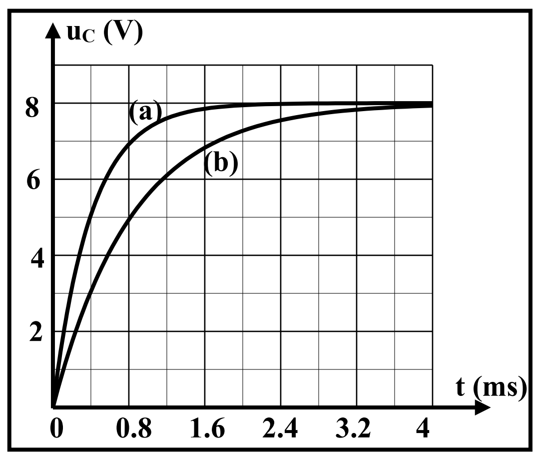
1.3) Verify that the capacitor becomes practically fully charged at t = 5 RC.

1.4) Indicate the effect of the resistance of the resistor on the duration of the charging of the capacitor.

2. Experimental study

We adjust R to two different values R_1 and R_2; an appropriate device allows to trace, for each value of R, the voltageu_C as a function of time (Doc. 3).

- curve (a) corresponds to $R = R_1$.
- curve (b) corresponds to $R = R_2$.



Doc. 3

2.1) Using the curves of document 3:

2.1.1) specify the value of E;

2.1.2) specify, without calculation, whether the value of R_2 is: equal to, greater than, or less than the value of R_1;

2.1.3) determine the values of R_1 and R_2.

2.2) The capacitor is fully charged, the electric energy stored in the capacitor is W_C.

2.2.1) Is the value of W_C affected by the resistance of the resistor? Justify.

2.2.2) Deduce the value of W_C.

Exercise 3 **(6 points)**

The nuclear bomb of Hiroshima

On August 6, 1945, an atomic (nuclear) bomb, fueled by highly enriched uranium (uranium-235), dropped on Hiroshima. It caused a violent explosion due to the chain nuclear fission of that uranium.

The bomb contained M = 52 kg ofuranium-235, only a small part of mass "m" of these nuclei was fissioned before the explosion ejected the material of the bomb away.

The aim of this exercise is to study nuclear fission and to determine the percentage of uranium-235 that was fissioned in that bomb.

1. Studying of the nuclear fission reaction

When the fissionable nucleus uranium-235 is bombarded by a thermal neutron ${}_0^1n$, it splits into two lighter nuclei with the emission of some neutrons.

One of the possible reactions is:

$$ {}_0^1n + {}_{92}^{235}U \rightarrow {}_{53}^{A}I + {}_{B}^{94}Y + 3\,{}_0^1n $$

Given: m_n = 1.00866 u;

m(${}_{92}^{235}U$) = 234.99332 u;

m (${}_{53}^{A}I$) = 138.89700 u;

m(${}_{B}^{94}Y$) = 93.89014 u;

1u = 1.66×10^{-27}kg;

c = 3×10^{8}m/s.

1.1) This reaction leads to a nuclear chain reaction. Why?

1.2) Calculate, indicating the used laws, the values of A and B.

1.3) Determine the mass defect Δm, which is converted into energy, in the above fission nuclear reaction.

1.4) Deduce that, 0.08 % of the mass of one uranium-235nucleusthat undergoes this fission is converted into energy.

2. Determination of the percentage of uranium-235 used in the bomb of Hiroshima

In nuclear bomb, the nuclear reactions are uncontrolled. The large amount of the released energy creates a nuclear explosion. The bomb dropped on Hiroshima released an amount of energy equivalent to the energy liberated by 14 kilotons of TNT.

2.1) Calculate the total nuclear energy liberated by the atomic bomb, knowing that each 1 kiloton of TNT liberates energy of 4×10^{12}J.

2.2) Deduce that the mass of uranium-235 nuclei, converted into energy during the explosion of the bomb, is Δm' = 622.22 mg.

2.3) The mass of uranium-235 that undergoes fission in the bomb is "m". Assume that, 0.08% of "m" is converted into energy. Calculate "m".

2.4) Out of M = 52 kg ofuranium-235, calculate the percentage of the mass of uranium-235 that was fissioned in the bomb of Hiroshima.

Exercise 1 (7 points)

Determination of the stiffness of a spring

Part	Answer	Mark
1	$ME_A = ME_O$, then $m\ g\ h_G + 0 = ½\ mV_1^2 + 0$, so $V_1 = \sqrt{2\ g\ h_G} = \sqrt{2 \times 10 \times 0.05} = 1$ m/s	0.75
2	During collision, the linear momentum of the system (S_1, S_2) must be conserved: $\vec{P}_{\text{juste before}} = m\ \vec{V}_1 + \vec{0} = m \times 1\vec{i}$; $\vec{P}_{\text{juste before}} = \vec{P}_{\text{juste after}}$ $\vec{P}_{\text{juste after}} = \vec{0} + m\ \vec{V}_o = m \times 1\ \vec{i}$ It's verified **Or** : During collision, the linear momentum of the system (S_1, S_2) is conserved: $m\ \vec{V}_1 + \vec{0} = \vec{0} + m\ \vec{V}_o$ therefore $\vec{V}_o = \vec{V}_1$ Then $V_o = 1$ m/s it's verified. **Or** : conservation of kinetic energy	0.75
3 — 3.1	$ME = \frac{1}{2}\ m\ v^2 + \frac{1}{2} k\ x^2$ The sum of the work done by the non-conservative forces is zero, so ME is conserved: $\frac{dEm}{dt} = 0 = 2\ (\frac{1}{2}\ m\ vv') + 2\ (\frac{1}{2}\ k\ xx')$, but $x' = v$ and $v' = x''$, then $v\ (m\ x'' + k\ x) = 0$, but $v = 0$ is rejected, som $x'' + k\ x = 0$, therefore $x'' + \frac{k}{m}\ x = 0$	1
3 — 3.2 — 1	$x' = \frac{A\ 2\pi}{T_o} \cos\left(\frac{2\pi}{T_o} t\right)$, $x'' = -A \left(\frac{2\pi}{T_o}\right)^2 \sin\left(\frac{2\pi}{T_o} t\right) = -\left(\frac{2\pi}{T_o}\right)^2 x$. Substitute in the differential equation, then $-\left(\frac{2\pi}{T_o}\right)^2 x + \frac{k}{m} x = 0$ $x\ [-\left(\frac{2\pi}{T_o}\right)^2 + \frac{k}{m}] = 0$, but $x = 0$ is rejected , so $T_o = 2\pi\sqrt{\frac{m}{k}}$	1
3 — 3.2 — 2	$V = x' = \frac{2\pi}{T_0} A \cos\left(\frac{2\pi}{T_0} t\right)$ At $t_o = 0$, $v' = V_o = \frac{A\ 2\pi}{T_o} \cos(0)$, then $A = \frac{T_o V_o}{2\pi}$	1
3 — 3.2 — 3	A is the amplitude of the oscillation of (S_2)	0.25
4	$T_o = 2\ t_1 = 2 \times 0.314 = 0.628$ s	0.5
5	$A = \frac{0.628 \times 1}{2 \times 3.14} = 0.1$ m	0.5
6	First method: $T_o = 2\pi\sqrt{\frac{m}{k}}$, then $k = \frac{4\pi^2 \times m}{T_o^2} = \frac{4 \times 3.14^2 \times 0.4}{0.628^2} = 40$ N/m. Second method: system [(S_2), (R), Earth] $½\ m\ V_o^2 + 0 = ½\ k\ A^2 + 0$, so $k = \frac{m\ V_o^2}{A^2} = \frac{0.4 \times 1^2}{0.1^2} = 40$ N/m.	0.5 0.75

Exercise 2 (7 points)

Effect of resistance on the charging process of a capacitor

Part			Answer	Mark
1	1.1		$u_{AM} = u_{AD} + u_{DF} + u_{FM}$,so E = u_C+ R i The positive sense is directed towards the plate of charge q, so $i = +\frac{dq}{dt}$, then $i = C\frac{du_C}{dt}$. $E = u_C + RC\frac{du_C}{dt}$, therefore $\frac{du_C}{dt} + \frac{u_C}{RC} = \frac{E}{RC}$.	0.75
	1.2		$u_C = A + B e^{Dt}$, so $\frac{du_C}{dt} = BD e^{Dt}$, substitute in the differential equation $BD e^{Dt} + \frac{A + B e^{Dt}}{RC} = \frac{E}{RC}$, then $RC B D e^{Dt} + A + Be^{Dt} = E$ $Be^{Dt}(RC D + 1) + A = E$. A = E ; and $Be^{Dt}(RC D + 1) = 0$. But $Be^{Dt} = 0$ is rejected, then (R C D + 1) = 0 , thus $D = -\frac{1}{RC}$. At $t_o = 0$, $u_C = 0 = A + B e^{Dt}$, so 0 = A + B , then B = - A, therefore B = - E .	1.25
	1.3		$u_C = E(1 - e^{\frac{-t}{RC}})$ At t = 5 RC: $u_C = E(1 - e^{\frac{-5RC}{RC}}) = E(1 - e^{-5})$, then $u_C = 0.99$ E. Therefore, the capacitor becomes practically fully charged at t = 5 R C.	0.75
	1.4		With higher resistance, the charging time (5 R C) increases, therefore the charging process becomes slower.	0.5
2	2.1	1	When the steady state is attained, the capacitor becomes fully charged, then u_C = E. Graphically, steady state is attained when u_C = 8 V. Therefore E = 8 V.	0.75
		2	On the graph, $u_{C(b)} < u_{C(a)}$ at any instant (except for 0), so the charging process in curve (b) is slower, thus $R_2 > R_1$.	0.75
		3	At t = τ, $u_C = 0.63\ E = 0.63 \times 8 = 5$ V. Graphically, u_C = 5 V ,when : $t = \tau_1 = 0{,}4$ms for curve (a) and $t = \tau_2 = 0{,}8$ ms for courbe (b). $\tau = R_1C$, donc $R_1 = \frac{0.4 \times 10^{-3}}{4 \times 10^{-6}}$; $R_1 = 100\ \Omega$ similarly $R_2 = 200\ \Omega$	1,25
	2.2	2.	$W_C = \frac{1}{2}C E^2$, then W_C depends only on C and E. Therefore the value of W_C is not affected by the value the resistance of the circuit.	0.5
		2.	$W_C = \frac{1}{2}C E^2 = \frac{1}{2}(4 \times 10^{-6})(8^2)$, therefore $W_C = 1.28 \times 10^{-4}$ J.	0.5

Exercise 3 (6 points)

The nuclear bomb of Hiroshima

Part		Answer	Mark
1	1.1	Since each nuclear reaction liberates 3 neutrons.	0.5
	1.2	Law of conservation of mass number: 1+ 235 = A + 94 + 3(1) then A = 139 Law of conservation of charge number: 0+ 92 = 53 + B + 3(0) then B = 39	1
	1.3	$\Delta m = m_{before} - m_{after} = (1.00866 + 234.99332) - [138.897 + 93.89014 + 3(1.00866)]$ $\Delta m = 0.18904u$.	0.75
	1.4	$\frac{\Delta m}{m(U)} = \frac{0.18904}{234.99332} = 0.0008 = 0.08\ \%$	0.75
2	2.1	$E_{\text{total liberated by the atomic bomb}} = 14 \times 4 \times 10^{12} = 56 \times 10^{12}$ J	0.5
	2.2	$E_{\text{total liberated by the atomic bomb}} = \Delta m' \times c^2$ Then $\Delta m' = \frac{56\times10^{12}}{(3\times10^8)^2} = 0.00062222\text{kg} = 0.62222\text{g} = 622.22\text{mg}$.	1
	2.3	0,08% m = Δm' then : $m = \frac{\Delta m'}{0.08\%} = \frac{0.62222}{0.0008} = 777.775\text{ g} = 0.777\text{ kg}$.	0.75
	2.4	Ratio $= \frac{m}{M} = \frac{0.777}{52} = 0.015 = 1.5\%$. Pourcentage $= \frac{m}{M}\times100 = \frac{0.777}{52}\times100 = 1.5$	0.75

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

Exercise 1 (7 points) Horizontal elastic pendulum

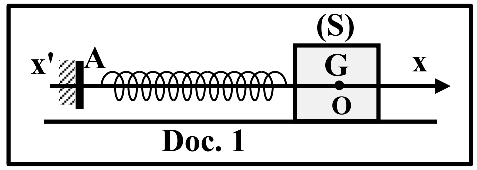
A mechanical oscillator is formed by a block (S) of mass m and a spring of negligible mass and spring constant k. (S) is attached to one end of the spring, and the other end of the spring is connected to a fixed support A. (S) can move without friction on a horizontal surface (Doc. 1).

The aim of this exercise is to determine the values of m and k.

At equilibrium, the center of mass G of (S) coincides with the origin O of the x-axis.

(S) is displaced horizontally in the positive direction.

At the instant $t_0 = 0$, the abscissa of G is x_0 and (S) is launched in the negative direction with an initial velocity $\overrightarrow{v_0} = v_0 \,\vec{i}$ ($v_0 < 0$) where $\vec{i}$ is the unit vector of the x-axis.



Doc. 1

At an instant t, the abscissa of G is x and the algebraic value of its velocity is $v = x' = \dfrac{dx}{dt}$.

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

1) Write, at an instant t, the expression of the mechanical energy of the system (Oscillator, Earth) in terms of x, m, k and v.

2) Establish the second order differential equation in x that governs the motion of (S).

3) Deduce the expression of the proper angular frequency ω_0 of the oscillations in terms of m and k.

4) The solution of the obtained differential equation is:
$x = X_m \sin(\omega_0 t + \varphi)$, where X_m, ω_0 and φ are constants.
Write the expression of v in terms of X_m, ω_0, φ and t.

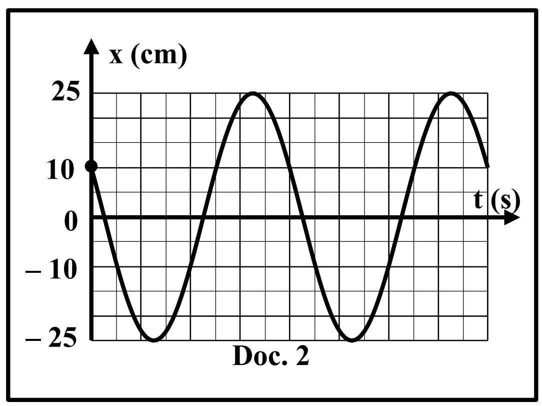
5) Write the expressions of x_0 and v_0 in terms of X_m, ω_0 and φ.

6) Deduce that: $X_m = \sqrt{x_0^2 + \dfrac{v_0^2}{\omega_0^2}}$.

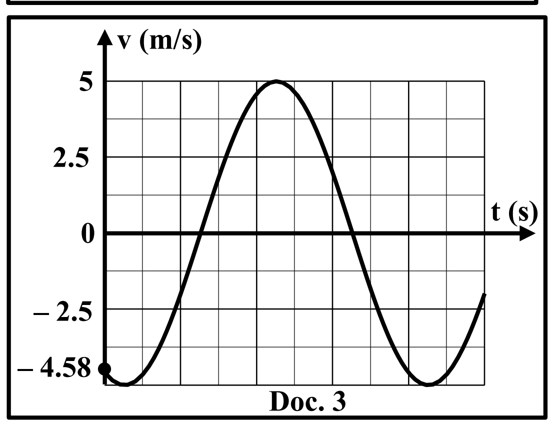
7) An appropriate device traces x and v as functions of time as shown in documents 2 and 3 respectively.
Referring to documents (2) and (3):

7-1) specify the type of the oscillations;

7-2) indicate the values of x_0, v_0, X_m and V_m, where V_m is the amplitude of v.



Doc. 2



Doc. 3

8) Deduce that ω_0 is approximately equal to 20 rad/s.

9) We repeat the same experiment by replacing the block (S) of mass m by another block (S') of mass m' = 0.8 kg.

The new proper angular frequency is $\omega' = \dfrac{\omega_0}{2}$.

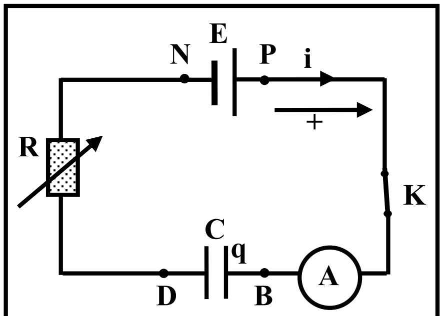
9-1) Write the expression of ω' in terms of m' and k.

9-2) Deduce the values of k and m.

Exercise 2 (7 points) Capacitance of a capacitor

The aim of this exercise is to determine the capacitance C of a capacitor.
We set-up the series circuit of document 4.
This circuit includes:

- an ideal battery of electromotive force E = 10 V;
- a rheostat of resistance R;
- a capacitor of capacitance C;
- an ammeter (A) of negligible resistance;
- a switch K.



Doc.4

Initially the capacitor is uncharged. We close the switch K at the instant $t_0 = 0$. At an instant t, plate B of the capacitor carries a charge q and the circuit carries a current i as shown in document 4.

1) Write the expression of i in terms of C and u_C, where $u_C = u_{BD}$ is the voltage across the capacitor.

2) Establish the differential equation that governs the variation of u_C.

3) The solution of this differential equation is of the form: $u_C = a + b\ e^{\frac{-t}{\tau}}$. Determine the expressions of the constants a, b and τ in terms of E, R and C.

4) Deduce that the expression of the current is: $i = \frac{E}{R}\ e^{\frac{-t}{RC}}$.

5) The ammeter (A) indicates a value $I_0 = 5$ mA at $t_0 = 0$. Deduce the value of R.

6) Write the expression of $u_R = u_{DN}$ in terms of E, R, C and t.

7) At an instant $t = t_1$, the voltage across the capacitor is $u_C = u_R$.

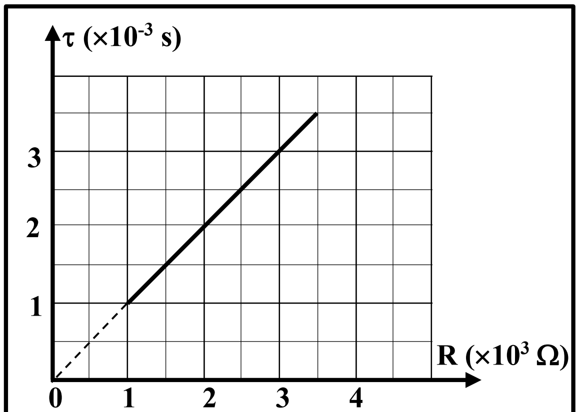
7-1) Show that $t_1 = R\,C\,\ell n\,2$.

7-2) Calculate the value of C knowing that $t_1 = 1.4$ ms.

8) In order to verify the value of C, we vary the value of R. Document 5 represents τ as a function of R.

8-1) Show that the shape of the curve in document 5 is in agreement with the expression of τ obtained in part 3.

8-2) Using the curve of document 5, determine again the value of C.



Doc. 5

Exercise 3 (6 points) Aspects of Light

The aim of this exercise is to show evidence of the two aspects of light.

1) First aspect

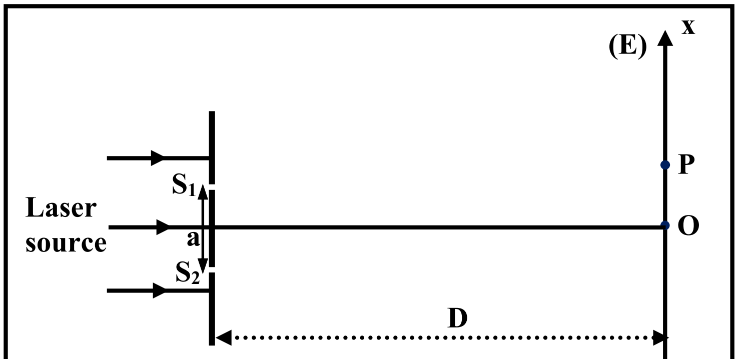
Consider Young's double-slit experiment. The two thin parallel horizontal slits S_1 and S_2 are separated by a distance a = 0.5 mm.

The screen (E) is placed parallel to the plane of the slits at a distance D = 2 m.

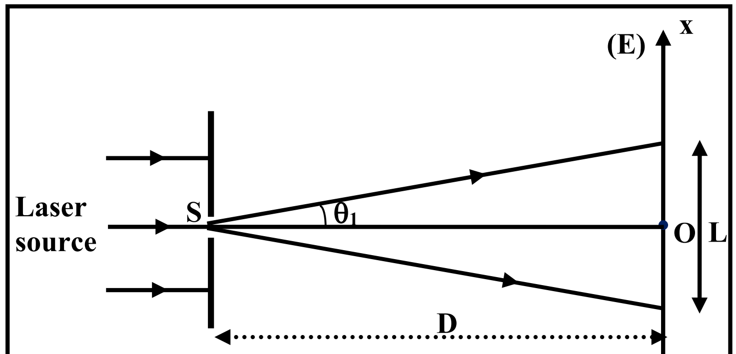
A laser source illuminates the two slits by a monochromatic light of wavelength λ = 600 nm in air, under normal incidence.

O is the point of intersection between the perpendicular bisector of $[S_1S_2]$ and the screen (E).

P is a point on the screen having an abscissa $x_P = \overline{OP} = 9.6$ mm (Doc. 6).



Doc. 6



Doc. 7

1-1) Calculate the inter-fringe distance i.

1-2) Specify the nature and the order of the fringe whose center is point P.

1-3) Slits S_1 and S_2 are replaced by a horizontal slit S of width a_1 = 0.1 mm. O is the center of the central bright fringe and $\alpha = 2\,\theta_1$ where α is the angular width of the central bright fringe (θ_1 is a small angle) (Doc. 7).

1-3-1) Name the phenomenon that takes place at the slit S.

1-3-2) Show that the width L of the central bright fringe is given by the expression: $L = \frac{2\lambda D}{a_1}$.

1-3-3) Deduce the distance d between O and the center of the first dark fringe.

1-3-4) Deduce that P is neither the center of a bright fringe nor the center of a dark fringe.

1-4) The previous two experiments show evidence of an aspect of light. Name this aspect.

2) Second aspect

The monochromatic radiation of wavelength λ = 600 nm in air, emitted by the laser source, illuminates now the surface of a lithium metal of work function W_0 = 2.39 eV.

Given:

Planck's constant $h = 6.6\times10^{-34}$ J.s ; 1 eV = 1.6×10^{-19} J

Take: the speed of light in air $c = 3\times10^{8}$ m/s.

2-1) Define the work function (extraction energy) of a metal.

2-2) Calculate, in eV, the energy of a photon in this radiation.

2-3) Deduce that there is no photoelectric emission from the surface of the lithium metal.

2-4) In order to extract electrons from the surface of the lithium metal, the laser source is replaced by another one emitting a radiation of wavelength λ' = 500 nm in air. Determine, in eV, the maximum kinetic energy of the liberated electrons.

2-5) This experiment shows evidence of an aspect of light. Name this aspect.

أسس التصحيح – مادة الفيزياء - إنكليزي

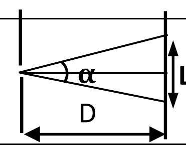
Exercise 1 (7 points) Horizontal elastic pendulum

Partie		Answer	Mark
1		$ME = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$	0.5
2		There is no friction therefore the mechanical energy is conserved. ME = constant , then $\frac{dME}{dt} = 0$, hence $m\,v\,v' + k\,x\,x' = 0$ with $v = x'$ and $v' = x''$ $x'(mv + kx) = 0$, but $x' = 0$ is rejected ; therefore, $x'' + \frac{k}{m}x = 0$	1
3		The differential equation is of the form: $x'' + \omega_0^2\,x = 0$ then : $\omega_0 = \sqrt{\frac{k}{m}}$	0.5
4		$v = X_m\,\omega_0\cos(\omega_0 t + \varphi)$	0.25
5		$x_0 = X_m\sin\varphi$ $v_0 = \omega_0 X_m\cos\varphi$	0.25 0.25
6		$\sin\varphi = \frac{x_0}{X_m}$ and $\cos\varphi = \frac{v_0}{\omega_0 X_m}$ $\sin^2\varphi + \cos^2\varphi = 1$ $\frac{x_0^2}{X_m^2} + \frac{v_0^2}{\omega_0^2 X_m^2} = 1$, so $X_m^2 = x_0^2 + \frac{v_0^2}{\omega_0^2}$ Therefore, $X_m = \sqrt{x_0^2 + \frac{v_0^2}{\omega_0^2}}$	1
7	7.1	Free undamped mechanical oscillations since x_m is constant	0.5
	7.2	$x_0 = 10$ cm ; $v_0 = -4.58$ m/s $X_m = 25$ cm ; $V_m = 5$ m/s	0.25 0.25 0.25 0.25
8		Substituting the values of x_0, v_0 and X_m into the expression of X_m gives : $0.25 = \sqrt{0.1^2 + \frac{-4.58^2}{\omega_0^2}}$, then $\omega_0 = 19.98 \cong 20$ rad/s **<u>Or</u>** : $V_m = \omega_0 X_m$, then $\omega_0 = \frac{V_m}{X_m} = \frac{5}{0.25} = 20$ rad/s	0.5
9	9.1	$\omega' = \sqrt{\frac{k}{m'}}$	0.25
	9.2	$\omega' = 10$ rad/s $k = m' \times \omega'^2 = 0.8 \times 10^2 = 80$ N/m $m = \frac{k}{\omega_0^2} = \frac{80}{400} = 0.2$ kg	0.5 0.5

Exercise 2 (7 points) Capacitance of a capacitor

<table>
<tr><th colspan="2">Part</th><th>Answer</th><th>notes</th></tr>
<tr><td colspan="2">1</td><td>$i = \frac{dq}{dt}$, but $q = C \times u_C$, then $i = C\frac{du_C}{dt}$</td><td>0.5</td></tr>
<tr><td colspan="2">2</td><td>$E = u_{BD} + u_{DN} = u_C + Ri$, but $i = C\frac{du_C}{dt}$; therefore, $E = u_C + RC\frac{du_C}{dt}$</td><td>0.75</td></tr>
<tr><td colspan="2">3</td><td>$\frac{du_C}{dt} = -\frac{b}{\tau}e^{-\frac{t}{\tau}}$; Substituting u_C and $\frac{du_C}{dt}$ in the differential equation gives :
$E = a + b\,e^{-\frac{t}{\tau}} + RC\left(-\frac{b}{\tau}\,e^{-\frac{t}{\tau}}\right)$, so $E = a + b\,e^{-\frac{t}{\tau}}\left(1 - \frac{RC}{\tau}\right)$
By comparison we obtain :
$a = E$ and $be^{-\frac{t}{\tau}}\left(1 - \frac{RC}{\tau}\right) = 0$, but $be^{-\frac{t}{\tau}} = 0$ is rejected ,then $1 - \frac{RC}{\tau} = 0$
Therefore, $\tau = RC$
At $t_o = 0$, the charge is $q_o = 0$, then $u_{C0} = 0$.
Substituting $u_{C0} = 0$ into the expression of u_C gives: $0 = a + b$, so $b = -a = -E$</td><td>2</td></tr>
<tr><td colspan="2">4</td><td>$i = C\frac{du_C}{dt} = C\frac{E}{\tau}e^{-\frac{t}{\tau}} = \frac{E}{R}e^{-\frac{t}{\tau}}$</td><td>0.5</td></tr>
<tr><td colspan="2">5</td><td>A $t_0 = 0$: $i = I_0 = \frac{E}{R}e^0$, then $I_0 = \frac{E}{R}$, thus $R = \frac{E}{I_0} = \frac{10}{5 \times 10^{-3}} = 2 \times 10^3\ \Omega$</td><td>0.5</td></tr>
<tr><td colspan="2">6</td><td>$u_R = Ri = RC\frac{du_C}{dt} = RC\frac{E}{\tau}e^{-\frac{t}{\tau}}$, then $u_R = E\ e^{-\frac{t}{\tau}}$</td><td>0.5</td></tr>
<tr><td rowspan="2">7</td><td>7.1</td><td>$u_C = u_R$
$E - Ee^{-\frac{t_1}{\tau}} = E\ e^{-\frac{t_1}{\tau}}$, so $E = 2E\ e^{-\frac{t_1}{\tau}}$, then $\frac{1}{2} = e^{-\frac{t_1}{\tau}}$, hence $-\ell n2 = -\frac{t_1}{\tau}$
Then, $t_1 = \tau\ \ell n2$; therefore, $t_1 = RC\ \ell n2$</td><td>0.75</td></tr>
<tr><td>7.2</td><td>$C = \frac{t_1}{R\,\ell n2} = \frac{1.4 \times 10^{-3}}{2 \times 10^3 \times \ell n\,2} = 1 \times 10^{-6}$ F</td><td>0.5</td></tr>
<tr><td rowspan="2">8</td><td>8.1</td><td>The curve is a straight line passing through the origin with a positive slope, then it is in agreement with the expression $\tau = RC$.</td><td>0.5</td></tr>
<tr><td>8.2</td><td>Slope $= C = \frac{\Delta\tau}{\Delta R} = \frac{3 \times 10^{-3}}{3 \times 10^3} = 1 \times 10^{-6}$ F</td><td>0.5</td></tr>
</table>

Exercise 3 (6 points)   Aspects of Light

Part			Answer	Mark
1	1.1		$i = \frac{\lambda D}{a} = \frac{600 \times 10^{-9} \times 2}{0.5 \times 10^{-3}} = 24 \times 10^{-4}$ m = 2.4 mm	0.5
	1.2		x_P = 9.6 mm = 4 i , then P is the center of the 4^{th} bright fringe. **Or**: P is the center of a bright fringe if $x_P = \frac{k \lambda D}{a}$ with $k \in Z$. $x_P = \frac{k \lambda D}{a}$, then $k = \frac{a\, x_P}{\lambda D} = \frac{0.5 \times 10^{-3} \times 9.6 \times 10^{-3}}{600 \times 10^{-9} \times 2} = 4 \in Z$, then P is the center of the 4^{th} bright fringe.	1
	1.3	1.3.1	Diffraction of light	0.25
		1.3.2	From the figure: $\tan\frac{\alpha}{2} = \frac{L/2}{D}$, but α is small then $\tan\alpha \cong \alpha$ So $\frac{\alpha}{2} = \frac{L}{2D}$ But $\alpha = \frac{2\lambda}{a_1}$; therefore, $L = \frac{2 \lambda D}{a_1}$  	0.75
		1.3.3	$d = \frac{L}{2} = \frac{2 \times 600 \times 10^{-9} \times 2}{2 \times 0.1 \times 10^{-3}}$ = 0.012 m = 12 mm	0.5
		1.3.4	$x_P < d = \frac{L}{2}$, then it is neither the center of a bright nor the center of a dark fringe.	0.25
	1.4		Wave aspect of light	0.25
2	2.1		W_o is the minimum energy needed to extract an electron from the surface of a metal.	0.5
	2.2		$E_{ph} = \frac{h c}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{600 \times 10^{-9}} = 3.3 \times 10^{-19}$ J $E_{ph} = \frac{3.3 \times 10^{-19}}{1.6 \times 10^{-19}}$ = 2.0625 eV	0.75
	2.3		$E_{ph} < W_o$, then there is no photoelectric emission.	0.25
	2.4		$E'_{ph} = W_o + KE_{max}$, then $KE_{max} = E'_{ph} - W_o = \frac{h c}{\lambda'} - W_o$ $KE_{max} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{500 \times 10^{-9} \times 1.6 \times 10^{-19}}$ - 2.39 = 0.085 eV	0.75
	2.5		Corpuscular (particle) aspect of time	0.25

مسابقة في: مادة الفيزياء	الاسم:
المدّة: ساعتان	الرقم:

This exam is formed of three exercises in 3 pages.
The use of a non-programmable calculator is recommended.

Exercise 1 (7 points)

Characteristics of a coil and a capacitor

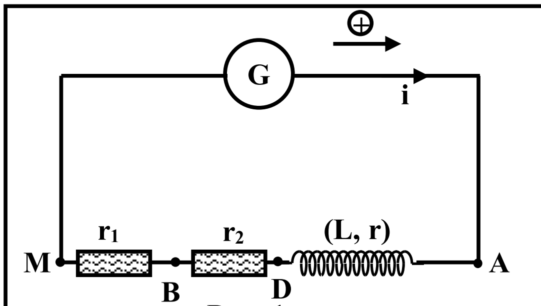
Consider:

- a generator G delivering an alternating sinusoidal voltage:
  $u_{AM} = u_G = U_m \cos(\omega t)$ (SI units);
- a coil of inductance L and resistance r;
- a capacitor of capacitance C;
- two resistors of resistances $r_1 = 10\ \Omega$ and $r_2 = 32\ \Omega$;
- an oscilloscope;
- connecting wires.

The aim of this exercise is to determine L, r and C.

1) Experiment 1

We set-up the circuit of document 1. The circuit thus carries an alternating sinusoidal current i. The oscilloscope, conveniently connected, allows us to display the voltage u_{AM} across the generator on channel (Y_1) and the voltage $u_{BM} = u_{r_1}$ across the resistor r_1 on channel (Y_2).

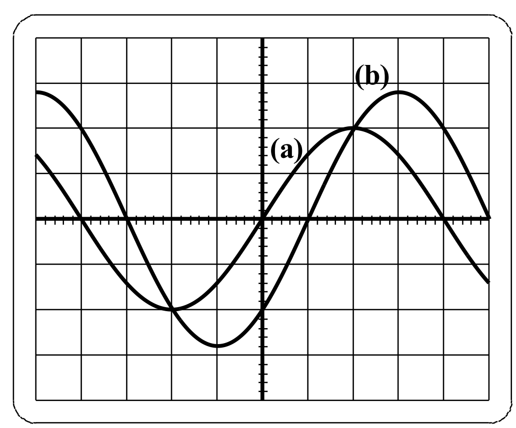


Doc. 1

The obtained waveforms are shown in document 2.

The adjustments of the oscilloscope are:

- vertical sensitivity on (Y_1): $S_{V1} = 5$ V/div;
- vertical sensitivity on (Y_2): $S_{V2} = 0.5$ V/div;
- horizontal sensitivity: $S_h = 2.5$ ms/div.



Doc. 2

1-1) Redraw the circuit of document 1 and show on it the connections of the oscilloscope.

1-2) The waveform (a) represents u_{AM}. Justify.

1-3) Referring to document 2, determine:

1-3-1) the angular frequency ω of the voltage u_{AM};

1-3-2) the amplitudes U_m and U_{m1} of the voltages u_{AM} and u_{BM} respectively;

1-3-3) the phase difference φ between u_{AM} and u_{BM}.

1-4) Write the expression of the voltage u_{BM} as a function of time.

1-5) Deduce the expression of the current i as a function of time.

1-6) Determine the values of L and r by applying the law of addition of voltages and by giving t two particular values.

2) Experiment 2

The capacitor is connected in series with the electric components of the circuit of document 1 (Doc. 3).

The oscilloscope, conveniently connected, allows us to display the voltage u_{AM} on channel (Y_1) and the voltage u_{BM} on channel (Y_2). The obtained waveforms are represented in document 4.

2-1) The circuit is the seat of current resonance. Justify.

2-2) In case of current resonance, the angular frequency ω of the generator is equal to the proper angular frequency ω_0 of the circuit.

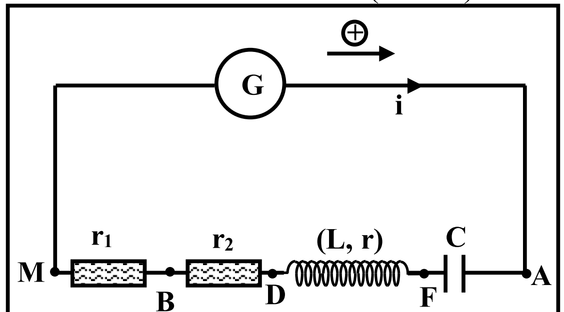
Choose, from the statements below, the one that describes correctly the proper angular frequency ω_0 of the circuit in document 3:

Statement 1: the proper angular frequency of the circuit is the angular frequency of u_G such that the current i and the voltage u across the coil are in phase.

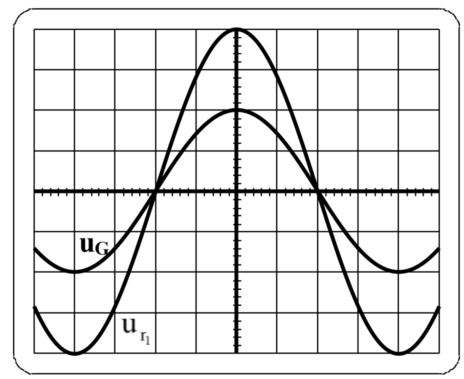
Statement 2: the proper angular frequency of the circuit is the angular frequency of u_G such that the amplitude I_m of the current i attains a maximum value.

Statement 3: the proper angular frequency of the circuit is the angular frequency of u_G such that the amplitude of the voltage across the coil attains a maximum value.

2-3) Write the relation among L, C and ω_0. Calculate C.



Doc. 3



Doc. 4

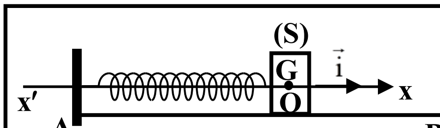
Exercise 2 (6.5 points)

Mechanical oscillator

Consider a mechanical oscillator formed of a spring, of negligible mass and spring constant k, and an object (S) of mass m.

The aim of this exercise is to determine k and m.

The spring is placed horizontally, connected from one of its extremities to a fixed support. (S) is attached to the other extremity of the spring and it may slide without friction on a horizontal rail AB and its center of mass G can move along a horizontal x-axis.



Doc. 5

At equilibrium, G coincides with the origin O of the x-axis (Doc. 5).

(S) is shifted from its equilibrium position and then released without initial velocity at the instant $t_0 = 0$. Thus, (S) performs mechanical oscillations.

At an instant t, the abscissa of G is $x = \overline{OG}$ and the algebraic value of its velocity is $v = \frac{dx}{dt} = x'$.

The horizontal plane containing G is considered as a reference level for gravitational potential energy.

1) The differential equation that describes the motion of G is: $2x'' + 200x = 0$ (SI units).
Use this differential equation to:

1-1) show that the motion of G is simple harmonic;

1-2) calculate the value of the proper angular frequency ω_0 of oscillations.

2) The time equation of the motion of G is of the form: $x = X_m \cos(\omega_0 t)$, where X_m is the amplitude of x.

2-1) Write the expression of v in terms of X_m, ω_0 and t.

2-2) Using the expressions of x and v, show that: $\omega_0^2 = \frac{v^2}{X_m^2 - x^2}$.

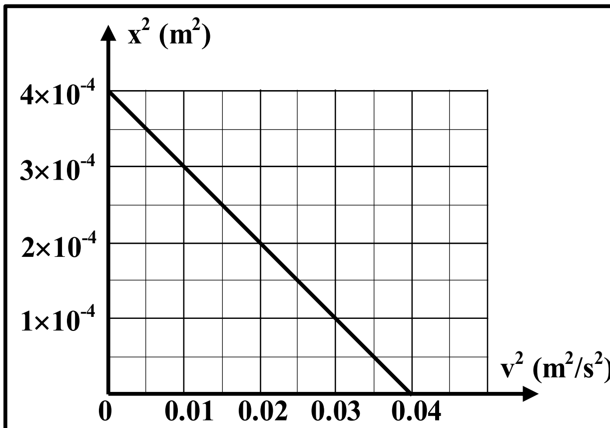
3) Applying the principle of conservation of mechanical energy «ME» of the system [(S), spring, Earth], show that: $x^2 = a v^2 + b$, where «a» and «b» are two constants to be determined in terms of k, m and ME.

4) Document 6 shows x^2 as a function of v^2.
Using document 6:

4-1) calculate X_m;

4-2) calculate again the value of ω_0.

5) Determine the values of k and m knowing that ME = 0.04 J.



Doc. 6

Exercise 3 (6.5 points)

Dating of a volcanic rock

Some of the volcanic rocks contain the radioactive isotope of potassium $^{40}_{19}K$ of half-life T and radioactive constant λ.

A small proportion of this isotope decays into argon $^{40}_{18}Ar$.

The aim of this exercise is to determine the age of a volcanic rock.

1) Indicate the composition of the potassium $^{40}_{19}K$ nucleus.

2) The decay equation of potassium-40 into argon-40 is: $^{40}_{19}K \rightarrow ^{40}_{18}Ar + ^{A}_{Z}X$.

2-1) Determine Z and A, indicating the used laws.

2-2) Name the emitted particle $^{A}_{Z}X$.

3) A sample of a volcanic rock contains at the instant of its formation, $t_0 = 0$, N_0 nuclei of potassium-40 that decay into argon-40.

3-1) Write the expression of the remaining number N_K of potassium-40 nuclei in terms of N_0, t and λ.

3-2) Deduce that the number of the formed argon-40 nuclei is: $N_{Ar} = N_0\,(1 - e^{-\lambda t})$.

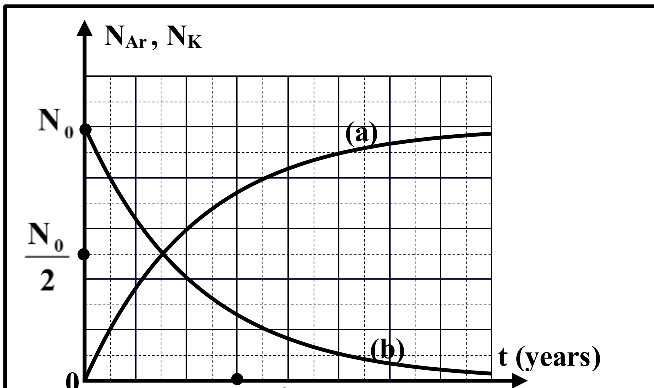
3-3) Determine, in terms of λ, the expression of t when $N_{Ar} = N_K$.

4) The curves (a) and (b) of document 7 represent N_K and N_{Ar} as functions of time.

4-1) Specify the curve that represents N_K.

4-2) Determine graphically the half-life T of potassium-40.

4-3) Deduce the value of λ.



Doc. 7

5) The sample of the volcanic rock contains at the instant of its formation, $t_0 = 0$, N_0 nuclei of potassium-40 that decay into argon-40. At this instant the sample does not contain any argon-40 nucleus.
At an instant t:

- N_K is the remaining number of nuclei of N_0 of potassium-40;
- N_{Ar} is the formed number of the argon-40 nuclei.

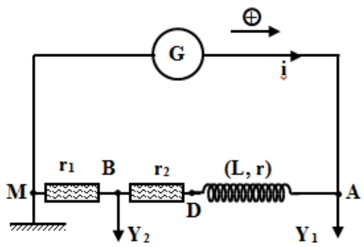
A geologist analyzes this sample to determine the age of the volcanic rock. He finds that the number N_{Ar} of argon-40 nuclei is 3 times the number N_K of potassium-40 nuclei.

5-1) Show that $\frac{N_0}{N_K} = 4$.

5-2) Deduce the age of the rock.

<u>Exercise 1</u> (7 points)

Characteristics of a coil and a capacitor

Part			Answer	Mark
1	1.1			0.5
	1.2		In the R-L series circuit, u_G leads i. Since curve (a) leads curve (b) , then it represents u_{AM}.	0.5
	1.3	1	$T = S_h \times x = 2.5 \times 8 = 20$ ms $= 20 \times 10^{-3}$ s then $\omega = \frac{2\pi}{T} = \frac{2\pi}{20\times10^{-3}} = 100\,\pi$ rad/s	0.75
		2	$U_m = S_{v1} \times y_1 = 2 \times 5 = 10$ V $U_{m1} = S_{v2} \times y_2 = 2.8 \times 0.5 = 1.4$ V	0.75
		3	$\varphi = \frac{2\pi\times d}{D} = \frac{2\pi\times 1\text{ div}}{8\text{ div}} = \frac{\pi}{4}$ rad	0.5
	1.4		u_{AM} leads u_{BM} by $\frac{\pi}{4}$ rad. $u_{BM} = 1.4\cos(100\,\pi t - \frac{\pi}{4})$ (u_{BM} in V and t in s)	0.5
	1.5		$U_{BM} = r_1 \times i$, then $i = \frac{u_{BM}}{r_1} = 0.14\cos(100\,\pi t - \frac{\pi}{4})$ (i in A and t in s)	0.5
	1.6		$u_{AM} = u_{AD} + u_{DB} + u_{BM}$ $U_m\cos(\omega t) = ri + L\frac{di}{dt} + r_2\, i + r_1 i$ $U_m\cos(\omega t) = r \times 0.14\cos(100\,\pi t - \frac{\pi}{4}) + L\,[-14\sin(100\,\pi\, t - \frac{\pi}{4})] + (r_2 + r_1)\,0.14\cos(100\,\pi\, t - \frac{\pi}{4})$ For $t = \frac{\pi}{4\omega}$ ($\omega t = \frac{\pi}{4}$) : $U_m\frac{\sqrt{2}}{2} = r \times 0.14 + 0 + (r_2 + r_1)\,0.14$ $5\sqrt{2} = 0.14\,r + 42 \times 0.14$; we calculate $r = 8{,}5\ \Omega$ For $\omega t = 0$: $U_m = r \times 0.14 \times \frac{\sqrt{2}}{2} + 14\,L\pi\,\frac{\sqrt{2}}{2} + (r_2 + r_1)\,0.14\,\frac{\sqrt{2}}{2}$ $10 = 8.5 \times 0.14 \times \frac{\sqrt{2}}{2} + 14\,L\pi\,\frac{\sqrt{2}}{2} + 42 \times 0.14\,\frac{\sqrt{2}}{2}$ we calculate $L = 0{,}16$ H	0.5 0.5 0.5
2	2.1		u_G and u_{r1} are in phase, with u_1 is the image of i.	0.25
	2.2		Statement 2	0.5
	2.3		In the case of current resonance, we have $\omega_G = \omega_0 = 100\,\pi$ and $LC\omega_0^2 = 1$ Then, $C = 6.33 \times 10^{-5}$ F	0.25 0.5

Exercise 2 **(6.5 points)**

Mechanical oscillator

Part		Answer	Mark
1	1.1	The differential equation $2x'' + 200x = 0$ can be written as: $x'' + 100x = 0$. Then, it has the form of: $x'' + \omega_0^2 x = 0$ This equation governs a simple harmonic motion of G.	**0.75**
	1.2	$\omega_0^2 = 100$; $\omega_0 = 10$ rad/s	**0.5**
2	2.1	$x = X_m \cos(\omega_0 t)$ $v = x' = -\omega_0 X_m \sin(\omega_0 t)$	**0.5**
	2.2	$\frac{x^2}{X_m^2} = \cos^2\omega_0 t$ and $\frac{v^2}{\omega_0^2 X_m^2} = \sin^2\omega_0 t$ $\sin^2\omega_0 t + \cos^2\omega_0 t = 1$, then $\frac{x^2}{X_m^2} + \frac{v^2}{\omega_0^2 X_m^2} = 1$ $\omega_0^2 X_m^2 = \omega_0^2 x^2 + v^2$, then $\omega_0^2(X_m^2 - x^2) = v^2$ $\omega_0^2 = \frac{v^2}{X_m^2 - x^2}$, then verified	**0.75**
3		ME = constant, then $\frac{1}{2}mv^2 + \frac{1}{2}kx^2 = ME$ $\frac{1}{2}kx^2 = ME - \frac{1}{2}mv^2$ then $x^2 = \frac{2ME}{k} - \frac{mv^2}{k}$ $x^2 = -\frac{m}{k}v^2 - \frac{2ME}{k}$ this equation has the form: $x^2 = av^2 + b$ $a = -\frac{m}{k}$ and $b = \frac{2ME}{k}$	**1.25**
4	4.1	$X_m^2 = 4\times10^{-4}$ m^2, then $X_m = 2\times10^{-2}$ m = 2 cm	**0.5**
	4.2	When $x^2 = 0$, $v^2 = 0.04$, then v = 0.2 m/s $\omega_0^2 = 100$ then $\omega_0 = 10$ rad/s	**0.75**
5		At t = 0: $v_0 = 0$, $X_m = 2\times10^{-2}$ m ME = KE + EPE + GPE then: $0.04 = 0 + 0 + \frac{1}{2}kX_m^2$ $k = \frac{2\times0.04}{X_m^2} = \frac{2\times0.04}{4\times10^{-4}} = 200$ N/m When x = 0, $V_m = 0.2$ m/s $ME = \frac{1}{2}mV_m^2$ then: $m = \frac{2\times ME}{V_m^2} = \frac{2\times0.04}{0.04} = 2$ kg **OR:** $b = \frac{2\times ME}{k}$; $x^2 = av^2 + b$ if $v^2 = 0$, then $x^2 = 4\times10^{-4}$ m^2, then $4\times10^{-4} = b = \frac{2\times ME}{k}$ $k = \frac{2\times ME}{4\times10^{-4}} = 200$ N/m $a = -\frac{m}{k}$; $a = \frac{x^2 - x_0^2}{v^2 - v_0^2} = \frac{0-4\times10^{-4}}{0.04-0} = -10^{-2}$ $-10^{-2} = -\frac{m}{200}$ then m = 2 kg	**1.5**

<u>Exercise 3</u> (6.5 points)

Dating of a volcanic rock

Part		Answer	Mark
1		Number of protons Z = 19 Number of neutrons N = A – Z = 40 – 19 = 21	0.5
2	2.1	According to the law of conservation of mass number : 40 = 40 + A then A = 0 According to the law of conservation of charge number : 19 = 18 + Z then Z = 1	1
	2.2	${}^{0}_{1}X = {}^{0}_{1}e$, the emitted particle is positron	0.25
3	3.1	$N_K = N_0 \times e^{-\lambda t}$	0.5
	3.2	$N_{Ar} = N_0 - N_K = N_0 - N_0 \times e^{-\lambda t} = N_0 (1 - e^{-\lambda t})$	0.5
	3.3	$N_{Ar} = N_K$ then $N_0 (1 - e^{-\lambda t}) = N_0 \times e^{-\lambda t}$ then $1 - e^{-\lambda t} = e^{-\lambda t}$ then $2\, e^{-\lambda t} = 1$, so $e^{\lambda t} = 2$ then $\lambda t = \ln 2$ then $t = \frac{\ln 2}{\lambda}$	0.75
4	4.1	(b) represents N_K since N_K decreases exponentially as a function of time.	0.5
	4.2	When t = T, we have $N_K = \frac{N_0}{2}$. Graphically: $T = \frac{2.6\times10^9}{2} = 1.3\times10^9$ years	0.75
	4.3	$\lambda = \frac{\ln 2}{T} = \frac{0.693}{1{,}3\times10^9} = 0.533\times10^{-9}$ year^{-1} = 0.016 s^{-1}	0.5
5	5.1	$N_0 (1 - e^{-\lambda t}) = 3\times N_0 \times e^{-\lambda t}$ $1 = 3\times e^{-\lambda t} + e^{-\lambda t} = 4\, e^{-\lambda t}$ $e^{\lambda t} = 4$ Then, $N_K = \frac{N_0}{e^{\lambda t}} = \frac{N_0}{4}$. Then, $\frac{N_0}{N_K} = 4$ verified **<u>Or</u>**: $N_K = N_0 - N_{Ar} = N_0 - 3N_K$ then $4\, N_K = N_0$, so $\frac{N_0}{N_K} = 4$	0.5
	5.2	$\frac{N_0}{N_K} = 4$ $N_0 = 4\times N_K = 4\times N_0\, e^{-\lambda t}$ $\frac{1}{4} = e^{-\lambda t}$ then $-\lambda t = \ln(0.25)$ then $t = \frac{\ln(0{,}25)}{-\lambda} = \frac{\ln(0{,}25)}{-\ln 2 \times T} = 2T = 2.6\times10^9$ years **<u>OR :</u>** $N_K = \frac{N_0}{4} = \frac{N_0}{2^2}$. Then, $t = 2\,T = 2\times1.3\times10^9 = 2.6\times10^9$ years	0.75

مسابقة في مادة الفيزياء — الاسم:
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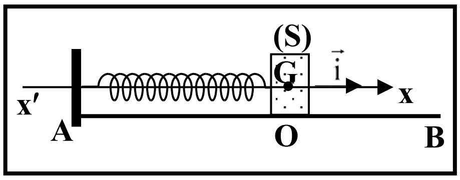
This exam is formed of three obligatory exercises in three pages.
The use of non-programmable calculators is allowed.

Exercise1 (7 points) Mechanical oscillator

Consider a mechanical oscillator constituted of an object (S) of mass m and a spring of negligible mass and stiffness k.

The aim of this exercise is to determine m and k.

The spring, placed horizontally, is fixed from one of its extremities to a fixed support and (S) is attached to the other extremity. (S) may slide without friction on a horizontal rail AB and its center of inertia G can move along a horizontal x- axis.



Doc.1

At equilibrium, G coincides with the origin O of the x-axis (Doc. 1).

At the instant $t_0 = 0$, G has an abscissa x_o and a velocity $\overrightarrow{v_0} = v_0\,\vec{i}$. Thus, (S) performs mechanical oscillations of amplitude X_m.

At an instant t, the abscissa of G is $x = \overline{OG}$ and the algebraic value of its velocity is $v = \frac{dx}{dt}$.

The horizontal plane containing G is considered as the reference level for gravitational potential energy.

1) Specify the type of oscillation of G.

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

3) Establish the second order differential equation in x that governs the motion of G.

4) Deduce, in terms of m and k, the expression of the proper (natural) period T_0 of the oscillations.

5) A solution of the obtained differential equation is: $x = 3 \sin(2.5\pi t)$; (x in cm and t in s).

5-1) Write, as a function of t, the expression of v.

5-2) Indicate the value of X_m.

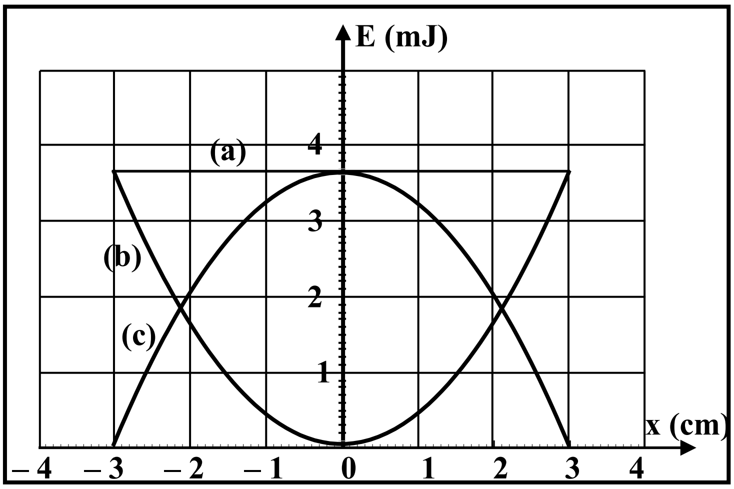
5-3) Calculate the values of x_0 and v_0.

5-4) Deduce the position of G and the direction of its displacement at $t_0 = 0$.

6) The curves (a), (b) and (c) of document 2 represent the kinetic energy KE of (S), the elastic potential energy PE_e of the spring and the mechanical energy ME of the system [(S), spring, Earth].

6-1) Match each curve to the appropriate energy. Justify.

6-2) Using document 2, determine the values of m and k.



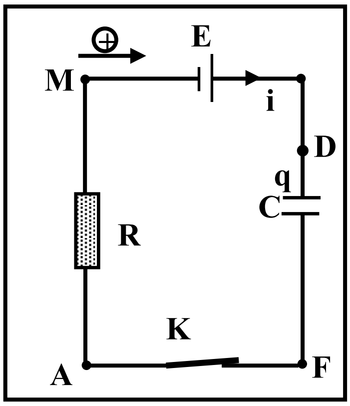
Doc. 2

Exercise 2 (6 points) Charging of a capacitor

The aim of this exercise is to determine the capacitance C of a capacitor.
For this aim, we set-up the series circuit of document 3 that includes:

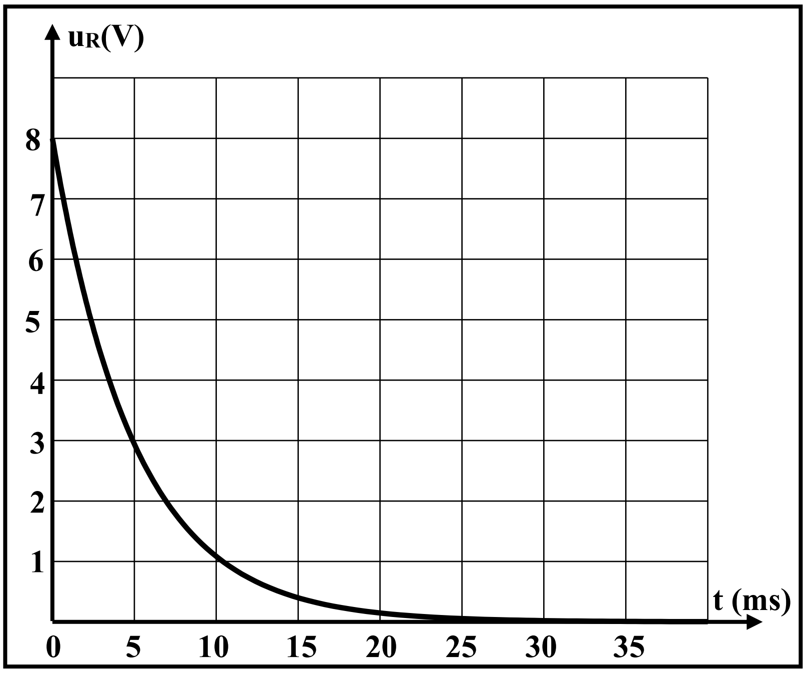
- an ideal battery (G) of emf E;
- a resistor of resistance R = 1 kΩ;
- a capacitor, initially uncharged, of capacitance C;
- a switch K.

We close the switch K at the instant $t_0 = 0$, and the charging process starts.
At an instant t, plate D of the capacitor carries a charge q and the circuit carries a current i.
An oscilloscope, conveniently connected, allows to display the voltage $u_{AM} = u_R$ across the resistor.



Doc. 3

1) Redraw the circuit of document 3 and show on it the connections of the oscilloscope.
2) Establish the differential equation that governs the variation of the voltage $u_{DF} = u_C$.
3) Show that $u_C = E\left(1 - e^{\frac{-t}{RC}}\right)$ is a solution of the established differential equation.
4) Deduce the expression of u_R in terms of E, R, C and t.
5) Document 4 shows u_R as a function of time.
5-1) Show that the shape of the curve is in agreement with the expression of u_R.
5-2) Specify the value of E.



Doc. 4

6) The time constant τ of the (R-C) series circuit is given by τ = RC. Choose, from the four statements below, two statements that describe correctly τ during the charging phase of the capacitor. Justify your answer.

Statement 1: τ is the time during which the voltage across the resistor is 37% of its maximum value.

Statement 2: τ is the time during which the voltage across the resistor attains its maximum value.

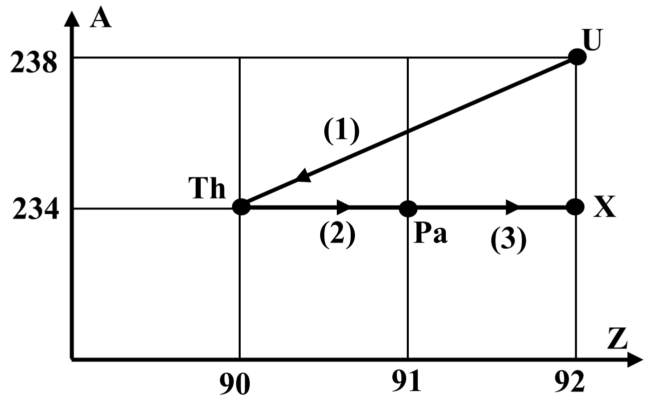
Statement 3: τ is a physical quantity that permits to slow down the establishment of the steady state.

Statement 4: τ is the time during which the voltage across the capacitor will be equal to that across the resistor.

7) Using document 4, determine the value of τ.
8) Deduce the value of C.

Exercise 3 (7 points) The radioactive family of uranium 238

Uranium 238 is a radioactive nuclide which decays to give a daughter nucleus which is radioactive; this nucleus disintegrates into another daughter nucleus, which can be also radioactive, and so on… These successive disintegrations will stop when the obtained daughter nucleus is stable. The set of these disintegrations constitutes a decay family (or series). A radioactive family is given the name of the first element constituting it.
The first four nuclei of the radioactive family of uranium 238 are given in document 5.



U: uranium; Th: thorium; Pa: protactinium

Doc. 5

Given:
Planck's constant $h = 6.6 \times 10^{-34}$ J.s;
$1 MeV = 1.6 \times 10^{-13} J$;
the speed of light in air $c = 3 \times 10^8$ m/s.

1) Specify the type of decay (α or β^-) for each of the disintegrations (1), (2) and (3) in document 5.

2) X and U are two nuclides of the same chemical element. Justify.

3) Disintegration (1) of uranium 238 is sometimes accompanied with the emission of a γ-ray.
The emitted particle during this disintegration, sometimes has a kinetic energy $KE_1 = 4.147$ MeV and sometimes has a kinetic energy $KE_2 = 4.195$ MeV. We suppose that uranium 238 is at rest and the kinetic energy of thorium 234 is negligible.

3-1) Indicate the cause of emission of a γ-ray.

3-2) Indicate the value of the kinetic energy of the emitted particle when this disintegration isn't accompanied with the emission of a γ-ray.

3-3) Deduce the energy of the γ-ray that accompanied the disintegration of uranium 238.

3-4) Calculate the wavelength λ_1 of the corresponding radiation.

4) The decay constant of uranium-238: $\lambda_2 = 4.9 \times 10^{-18}$ s^{-1}.

4-1) Calculate, in year, the half-life T of uranium 238.

4-2) Deduce why uranium 238 remains on Earth to the present days.

5) Uranium 238 can be found in some minerals. The radioactive activity of uranium 238 in a mineral sample is, at $t_0 = 0$, $A_0 = 8000$ Bq.

5-1) Determine the number N_0 of uranium nuclei in this sample at $t_0 = 0$.

5-2) Show, by calculation, that N_0 remains almost the same at $t_1 = 100$ years and at $t_2 = 1000$ years.

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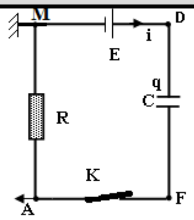
المدة: ساعتان — الرقم:

Exercise1 (7 points) **Mechanical oscillator**

Part		Answers	Note
1		Free un-damped mechanical oscillations , since there is no friction	0.5
2		$ME = KE + EPE = \frac{1}{2} m v^2 + \frac{1}{2} kx^2$	0.5
3		The oscillations are simple harmonic : ME = constant $\frac{dME}{dt} = 0$; $mvx'' + kxv = 0$; $v = 0$ is rejected, then $x'' + \frac{k}{m} x = 0$	0.75
4		The differential equation has the form: $x'' + \omega_0^2 x = 0$; $\omega_0 = \sqrt{\frac{k}{m}}$; $T_0 = \frac{2\pi}{\omega_0} = 2\pi\sqrt{\frac{m}{k}}$	0.5
5	5-1	$v = x' = 3 \times 2.5\pi \cos(2.5 \pi t) = 7.5\pi \cos(2.5 \pi t)$ $= 23.56 \cos(2.5 \pi t)$; v (cm/ s) & t (s)	0.5
	5-2	$X_m = 3$ cm	0.25
	5-3	At $t = 0$, $x_0 = 3 \sin(0) = 0$ $v_0 = 23.56 \cos(0) = 23.56$ cm/s	0.5 0.5
	5-4	G is at O since $x_0 = 0$ and it moves in the positive direction since $v_0 > 0$	0.25
6	6-1	Curve (a): ME, the oscillations are simple harmonic so ME = constant, Curve (b): EPE, since at t = 0 the object (S) is at O, so x = 0 and then EPE = 0 Curve (c) : KE, since when (S) at $x = X_m$ the speed of (S) is zero so KE = 0	0.5 0.5 0.5
	6-2	For $x = X_m = 0.03$ m ; $EPE = \frac{1}{2} k X_m^2 = 3.6$ mJ $= 3.6 \times 10^{-3}$ J ; k = 8 N/m For x = 0 ; $v = V_m = 23.26$ cm/s $= 23.26 \times 10^{-2}$ m/s ; $KE = \frac{1}{2} m V_m^2 = 3.6$ mJ $= 3.6 \times 10^{-3}$ J ; m = 0.13 kg	0.5 0.75

Exercise 2 (6 points) **Charging of a capacitor**

Part	Answers	Note
1		0.25
2	$i = \frac{dq}{dt}$, then $i = C\frac{du_C}{dt}$ $u_{DM} = u_{DF} + u_{FA} + u_{AM}$, thus $E = u_C + R\,i$ $E = u_C + RC\frac{du_C}{dt}$, then $\frac{du_C}{dt} + \frac{u_C}{RC} = \frac{E}{RC}$.	1
3	$u_c = E\left(1 - e^{-\frac{t}{R.C}}\right)$, so $\frac{d\,u_c}{d\,t} = \frac{E}{RC}e^{-\frac{t}{R.C}}$, replace in the differential equation: $\frac{E}{RC}e^{-\frac{t}{RC}} + \frac{E\left(1 - e^{-\frac{t}{R.C}}\right)}{R\,C} = \frac{E}{R\,C}$ $\frac{E}{R\,C} = \frac{E}{R\,C}$ so $u_c(t) = E\left(1 - e^{-\frac{t}{R.C}}\right)$ is a solution	0.75
4	$u_R = Ri = RC\frac{du_C}{dt} = RC\ \frac{E}{RC}e^{-\frac{t}{R,C}} = E\,e^{-\frac{t}{R,C}}$	0.5
5-1	$u_R = Ee^{-\frac{t}{R.C}}$ is a decreasing exponential function, from E to 0, which is in agreement with the graph of document 4	0.5
5-2	from the equation: at $t_0 = 0$: $u_R = E\,e^0 = E$ from the curve : at $t_0 = 0$: $u_R = 8$ V $\Rightarrow E = 8$ V	0.5
6	**Statement 1** : at $t = \tau$; $u_R = E\,e^{-\frac{\tau}{R.C}} = E\,e^{-1} = E \times 0.367 \approx 37\,\%\,E$ **Statement 3:** The steady state is attained after a time $t = 5\,\tau$;therefore, if we increase τ, the duration $5\,\tau$ increases, which slows down the establishment of the steady state.	0.75 0.75
7	a $t = \tau$; $u_R = 0.37 \times 8 = 2.96$ V, from the curve $\tau = 5$ ms	0.5
8	$\tau = R\,C$, then $C = \frac{\tau}{R} = 5 \times 10^{-6}$ F $= 5\ \mu$F	0.5

Exercise 3 (7 points) The radioactive family of uranium 238

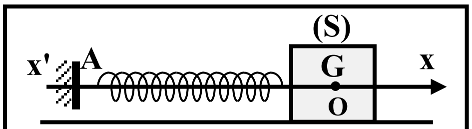
Part		Answers	Note
1		Disintegration (1) : ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$ then type α Disintegration (2) : ${}^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e$ then type β^- Disintegration (3) : ${}^{234}_{91}Pa \rightarrow {}^{234}_{92}X + {}^{0}_{-1}e$ then type β^-	**0.5** **0.5** **0.5**
2		Because they have the same charge number Z, they are isotopes of uranium.	**0.25**
3	3-1	The de-excitation of the daughter nucleus Th.	**0.25**
	3-2	When their isn't emission of gamma ray, kinetic energy of the emitted particle is $KE_2 = 4.195$ MeV	**0.25**
	3-3	When γ ray accompanied disintegration of uranium 238, kinetic energy of the emitted particle decreases, this decrease is due to the energy of the emitted gamma ray. So $E_\gamma = 0.048$ MeV	**0.25** **0.25**
	3-4	$E_\gamma = \frac{h.c}{\lambda_1}$; $\lambda_1 = \frac{h.c}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{0.048 \times 1.6 \times 10^{-13}} = 2.57 \times 10^{-11}$ m	**1**
4	4-1	$T = \frac{\ln 2}{\lambda_2} = \frac{\ln 2}{4.9 \times 10^{-18}} = 1.47 \times 10^{17}s \approx 4.6 \times 10^9$ years	**1**
	4-2	The half-life of uranium-238 is of the order of billions of years, therefore this nuclide needs a lot of time to disintegrate which explains its presence on Earth until today.	**0.5**
5	5-1	$A_0 = \lambda_2 N_0$; $N_0 = \frac{A_0}{\lambda_2} = \frac{8000}{4.9 \times 10^{-18}} = 1.63 \times 10^{21}$ nuclei	**1**
	5-2	$N = N_0 e^{-\lambda_2 t}$ $t_1 = 100$ years: $N = 1.63 \times 10^{21} e^{-4.9 \times 10^{-18} \times 100 \times 365 \times 14 \times 3600} \approx 1.63 \times 10^{21}$ $t_2 = 1000$ years: $N = 1.63 \times 10^{21} e^{-4.9 \times 10^{-18} \times 1000 \times 365 \times 14 \times 3600} \approx 1.63 \times 10^{21}$	**0.25** **0.25** **0.25**

مسابقة في مادة الفيزياء	الاسم:
المدة: ساعة ونصف	الرقم:

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

Exercise 1 (7 pts) Mechanical oscillator

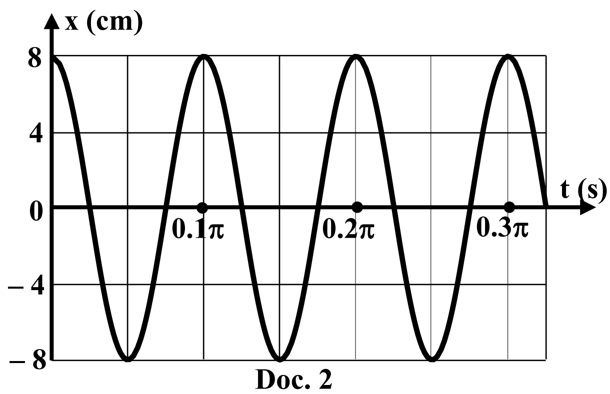
A mechanical oscillator is constituted of a block (S) of mass M and a spring of negligible mass and force constant k.
The spring, placed horizontally, is connected from one of its extremities to a fixed support A. (S) is attached to the other extremity of the spring and it may slide without friction on a horizontal surface (Doc. 1).



Doc. 1

The aim of this exercise is to determine the values of M and k.
At equilibrium, the center of mass G of (S) coincides with the origin O of the x-axis.
(S) is shifted from its equilibrium position in the positive direction and then released without initial velocity at the instant $t_0 = 0$. Thus, (S) performs mechanical oscillations. At an instant t, the abscissa of G is $x = \overline{OG}$ and the algebraic value of its velocity is $v = x' = \frac{dx}{dt}$.
The horizontal plane containing G is considered as a reference level for gravitational potential energy.

1) Write, at an instant t, the expression of the mechanical energy ME of the system (Oscillator, Earth) in terms of x, M, k and v.
2) Establish the second order differential equation in x that governs the motion of G.
3) Deduce that the expression of the proper (natural) period of the oscillations is $T_1 = 2\pi\sqrt{\frac{M}{k}}$.
4) An appropriate device traces x as a function of time (Doc. 2).
Referring to document 2, indicate:
4.1) the type of oscillations of G;
4.2) the amplitude X_m of the oscillations;
4.3) the value of T_1.



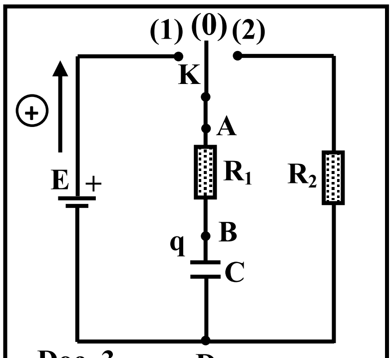
Doc. 2

5) The same experiment is repeated by putting on (S) an object, considered as a particle, of mass m = 50 g. The duration of 10 oscillations becomes $\Delta t = 3.67$ s.
5.1) Write the expression of the new proper (natural) period T_2 of the oscillations in terms of k, M and m.
5.2) Using the expressions of T_1 and T_2, show that $k = \frac{4\pi^2 m}{T_2^2 - T_1^2}$.
5.3) Determine the values of k and M.

Exercise 2 (7 pts) Charging and discharging a capacitor

The aim of this exercise is to study the charging and the discharging of a capacitor.
For this purpose, we set up the circuit of document 3 that includes:

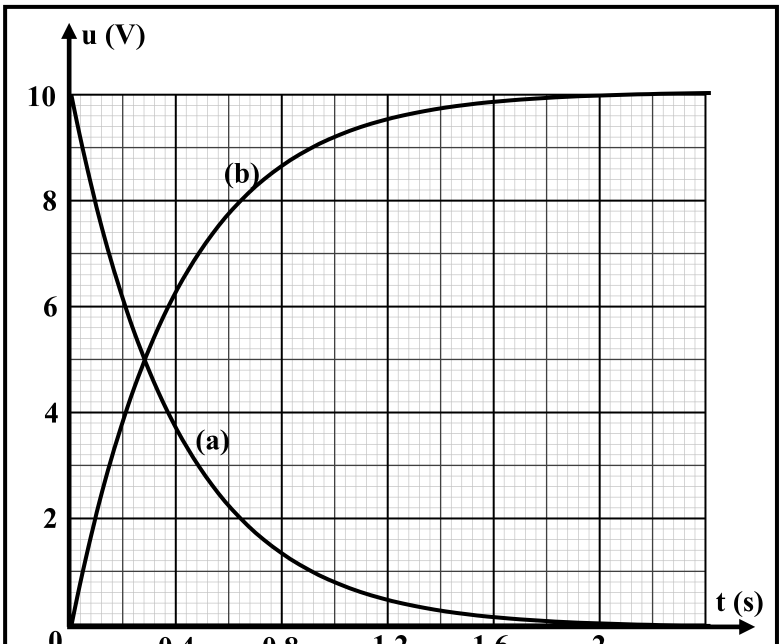
- an ideal battery of electromotive force E = 10 V;
- two resistors of resistances $R_1 = R_2 = 4\ k\Omega$;
- a capacitor of capacitance C;
- a switch K.



Doc. 3

1) Charging the capacitor

The switch K is initially at position (0) and the capacitor is uncharged.
At the instant $t_0 = 0$, K is turned to position (1) and the charging process of the capacitor starts.
At an instant t, plate B of the capacitor carries a charge q and the circuit carries a current i.
An appropriate device allows us to display the voltage $u_{AB} = u_{R_1}$ across the resistor and the voltage $u_{BD} = u_C$ across the capacitor.
Curves (a) and (b) of document 4 show these voltages as functions of time.



Doc. 4

1.1) Curve (a) represents u_{R_1} and curve (b) represents u_C. Justify.

1.2) The time constant of this circuit is given by $\tau_1 = R_1 C$.

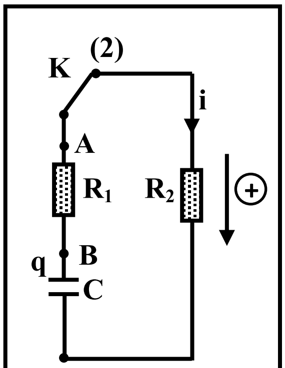
1.2.1) Using document 4, determine the value of τ_1.

1.2.2) Deduce the value of C.

1.3) Calculate the time « t_1 » needed by the capacitor to practically become completely charged.

2) Discharging the capacitor

The capacitor is completely charged. At an instant taken as a new initial time $t_0 = 0$, the switch K is turned to position (2), and the capacitor starts discharging through the resistors of resistances R_1 and R_2. At an instant t the circuit carries a current i (Doc. 5).



Doc. 5

2.1) Show, using the law of addition of voltages, that the differential equation which governs u_C is:

$$RC\frac{du_C}{dt} + u_C = 0 \text{ where } R = R_1 + R_2.$$

2.2) The solution of this differential equation is of the form: $u_C = E\,e^{\frac{-t}{\tau_2}}$ where τ_2 is the time constant of the circuit of document 5.
Determine the expression of τ_2 in terms of R and C.

2.3) Verify that the time needed by the capacitor to practically become completely discharged is $t_2 = 5\,\tau_2$.

3) Duration of charging and discharging the capacitor

Show, without calculation, that « t_2 » is greater than « t_1 ».

Exercise 3 (6 pts) **Characteristics of a coil**

In order to determine the inductance L and the resistance r of a coil, we connect it in series with a resistor of resistance $R = 30\ \Omega$ across a function generator (G) providing an alternating sinusoidal voltage of angular frequency ω.

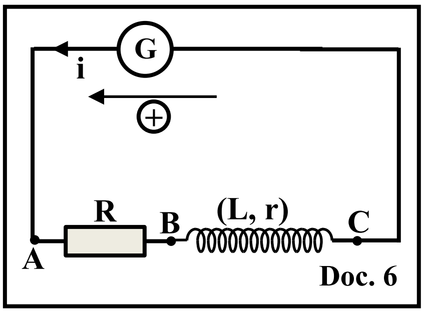
The circuit thus carries an alternating sinusoidal current of expression $i = I_m \sin(\omega t)$ (Doc. 6).

An oscilloscope allows us to display the voltage $u_{AB} = u_R$ across the resistor and the voltage $u_{BC} = u_L$ across the coil.

The obtained waveforms are shown in document 7.

The adjustments of the oscilloscope are:

- vertical sensitivity for both channels: $S_v = 2$ V/div;
- horizontal sensitivity: $S_h = 0.4$ ms/div.



Doc. 6

1) The voltage u_R represents the image of i. Why?

2) Referring to document 7, specify which of the curves, (a) or (b), leads the other.

3) Deduce that curve (a) corresponds to u_{AB}.

4) Using document 7, determine:

4.1) the angular frequency ω;

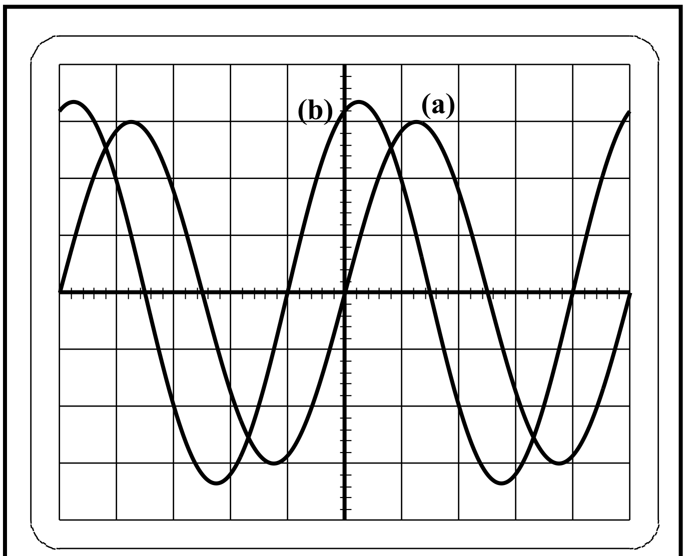
4.2) the maximum value I_m of i ;

4.3) the phase difference φ between u_L and i.

5) Prove that $u_L = 6.8 \sin(\omega t + 0.4\pi)$ (SI).

6) Knowing that the voltage across the coil is given by $u_L = r\,i + L\dfrac{di}{dt}$, write the expression of u_L in terms of r, L, ω and t.

7) Using the two expressions of u_L found in parts 5 and 6 and by giving «ωt» two particular values, determine the values of L and r.



Doc.7

مسابقة في مادة الفيزياء	الاسم:
المدة: ساعة ونصف	الرقم:

Exercise 1 (7 pts) **Mechanical oscillator**

Part		Answer	Note
1		$ME = KE + EPE = \frac{1}{2} M v^2 + \frac{1}{2} kx^2$	0.5
2		The sum of the works done by the non-conservative forces is zero, then the mechanical energy is conserved. (Or: Friction is neglected, then the mechanical energy is conserved). ME = constant , then $\frac{dME}{dt} = 0$, so $M v v' + k x x' = 0$, but $v = x'$ and $v' = x''$, hence $v (M x'' + k x) = 0$ $v = 0$ is rejected , then $x'' + \frac{k}{M} x = 0$	1
3		The differential equation is of the form: $x'' + \omega_0^2 x = 0$, with $\omega_o = \sqrt{\frac{k}{M}}$ $T_1 = \frac{2\pi}{\omega_o}$; therefore, $T_1 = 2\pi\sqrt{\frac{M}{k}}$	1
4	4.1	Free undamped mechanical oscillations	0.5
	4.2	$X_m = 8$ cm	0.5
	4.3	From the curve: $T_1 = 0.1\pi$ s = 0.314 s	0.5
5	5.1	$T_2 = 2\pi\sqrt{\frac{M+m}{k}}$	0.5
	5.2	$T_1^2 = 4\pi^2 \frac{M}{k}$ and $T_2^2 = 4\pi^2 (\frac{M+m}{k})$ $T_2^2 - T_1^2 = 4\pi^2 (\frac{M+m}{k} - \frac{M}{k}) = \frac{4\pi^2 m}{k}$, so $k = \frac{4\pi^2 m}{(T_2^2 - T_1^2)}$	1
	5.3	$T_2 = \frac{3.67}{10} = 0.367$ s $k = \frac{4\pi^2 \times 0.05}{0.367^2 - 0.314^2}$, then $k = 54.7$ N/m $T_1^2 = 4\pi^2 \frac{M}{k}$, substituting the value of k into this expression gives: $0.314^2 = 4\pi^2 \frac{M}{54.7}$; therefore, $M = 0.1366$ kg = 136.6 g	0.5 0.5 0.5

Exercise 2 (7 pts) **Charging and discharging of a capacitor**

Part		Answer	Note
1	1.1	Curve (a): $u_{AB} = u_{R_1} = R_1 i$; u_{R_1} is directly proportional to the current in the circuit. During the charging process the current decreases so u_{R_1} decreases. Curve (b) : $u_{BD} = u_C = \frac{q}{C}$; During charging process q increases so u_C increases	0.5 0.5
	1.2.1	At $t = \tau_1$: $u_C = 0.63\,E = 6.3$ V From document 4: $u_C = 6.3$ V at t = 0.4 s , then $\tau_1 = 0.4$ s	1
	1.2.2	$\tau_1 = R_1 C$, so $C = \frac{\tau_1}{R_1} = \frac{0.4}{4000}$, hence $C = 1 \times 10^{-4}$ F = 100 µF	0.5
	1.3	$t_1 = 5\tau_1 = 5 \times 0.4$, then $t_1 = 2$ s	0.5
2	2.1	$u_{BD} = u_{BA} + u_{AD}$ $u_C = R_1 i + R_2 i$, then $u_C = (R_2 + R_1)\, i = R\, i$ But, $i = -\frac{dq}{dt} = -C\frac{du_C}{dt}$, hence $u_C = -RC\frac{du_C}{dt}$ Therefore , $RC\frac{du_C}{dt} + u_C = 0$	1.5
	2.2	$u_C = E\,e^{\frac{-t}{\tau_2}}$, then $\frac{du_C}{dt} = -\frac{E}{\tau_2}e^{\frac{-t}{\tau_2}}$ Substituting u_C and $\frac{du_C}{dt}$ into the differential equation gives: $RC(-\frac{E}{\tau_2}e^{\frac{-t}{\tau_2}}) + E\,e^{\frac{-t}{\tau_2}} = 0$, so $E\,e^{\frac{-t}{\tau_2}}(1 - \frac{RC}{\tau_2}) = 0$ $E\,e^{\frac{-t}{\tau_2}} = 0$ is rejected , then $1 - \frac{RC}{\tau_2} = 0$, so $\tau_2 = RC$	1.5
	2.3	At $t = 5\,\tau_2$: $u_C = E\,e^{\frac{-5\tau_2}{\tau_2}} = E\,e^{-5} \cong 0$, so the capacitor is practically completely. discharged.	0.5
3		$t_1 = 5\,R_1 C$ and $t_2 = 5\,RC = 5\,(R_1 + R_2)\,C$ $(R_1 + R_2) > R_1$, then $t_2 > t_1$	0.5

Exercise 3 (6 pts) **Characteristics of a coil**

Part		Answer	Note
1		$u_R = Ri$, but R is a positive constant , then u_R and i are directly proportional ; therefore, u_R is the image of current.	0.5
2		Curve (b) leads curve (a), since curve (b) becomes maximum before curve (a).	0.5
3		The voltage across the coil u_L leads u_R (or i). Curve (b) leads curve (a), then curve (a) corresponds to $u_R = u_{AB}$.	0.5
4	4.1	$T = 5 \times 0.4 = 2$ ms $= 2\times10^{-3}$ s $\omega = \frac{2\pi}{T} = \frac{2\pi}{2\times10^{-3}}$, hence $\omega = 1000\,\pi$ rad/s	0.25 0.5
	4.2	Curve (a): $U_{R(max)} = 3 \times 2 = 6$ V $U_{R(max)} = R \times I_m$, then $I_m = \frac{6}{30} = 0.2$ A	0.25 0.5
	4.3	$\varphi = \frac{2\pi d}{D} = \frac{2\pi\times1}{5}$, then $\varphi = 0.4\,\pi$ rad	0.5
5		From curve (b): $U_{L(max)} = 3.4 \times 2 = 6.8$ V , and u_L leads i by $\varphi = 0.4\pi$ rad $u_L = U_{L(max)} \sin(\omega t + \varphi)$; therefore, $u_L = 6.8 \sin(\omega t + 0.4\,\pi)$	0.25 0.25
6		$u_L = r\,i + L\frac{di}{dt} = r\,I_m \sin(\omega t) + L\,I_m\,\omega \cos(\omega t)$ $u_L = 0.2\,r \sin(\omega\,t) + L\,(0.2)\,(1000\pi) \cos(\omega t) = 0.2\,r \sin(\omega t) + 200\pi\,L \cos(\omega t)$ (SI) **Or** $u_L = 0.2\,r \sin(\omega t) + \omega\,L\,(0.2) \cos(\omega t)$ (SI)	0.5
7		$6.8 \sin(\omega\,t + 0.4\,\pi) = 0.2\,r \sin(\omega t) + 200\,\pi\,L \cos(\omega t)$ For $\omega t = 0$: $6.8 \sin(0.4\,\pi) = 0 + 200\pi\,L$, then $L = 0.01$ H For $\omega t = \frac{\pi}{2}$ rad : $6.8 \sin(\frac{\pi}{2} + 0.4\,\pi) = 0.2\,r + 0$, then $r = 10.5\,\Omega$	0.75 0.75

	مسابقة في مادة الفيزياء	الاسم:
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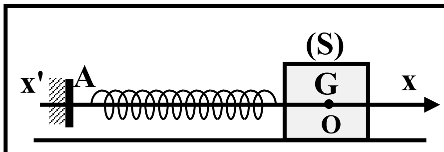
This exam is formed of three obligatory exercises in three pages.
The use of non-programmable calculator is recommended.

Exercise 1 (7 pts)

Mechanical oscillations

A mechanical oscillator consists of a block (S) of mass m = 50 g and a massless spring of force constant k. The horizontal spring is fixed from one of its ends to a fixed support A. (S) is attached to the other end of the spring and can move without friction on a horizontal surface (Doc. 1).



Doc.1

At equilibrium, the center of mass G of (S) coincides with the origin O of the x-axis.

(S) is shifted from its equilibrium position by a displacement x_0 and then it is released without initial velocity at an instant $t_0 = 0$. (S) then performs mechanical oscillations.

At an instant t, the abscissa of G is $x = \overline{OG}$ and the algebraic value of its velocity is $v = x' = \frac{dx}{dt}$.

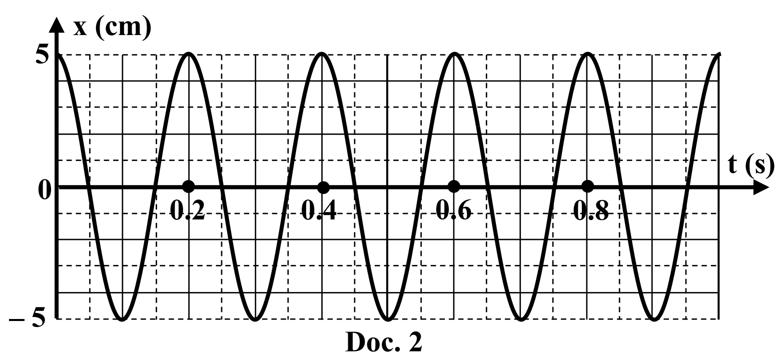
The aim of this exercise is to determine the maximum speed attained by G.

Take:

- the horizontal plane containing G as the reference level for gravitational potential energy;
- $\pi^2 = 10$.

1) The mechanical energy ME of the system (Oscillator - Earth) is conserved. Why?
2) Write the expression of ME in terms of m, v, k and x.
3) Determine the second order differential equation in x that governs the motion of G.
4) Deduce, in terms of m and k, the expression of the proper (natural) period T_0 of the oscillations.
5) An appropriate device shows x as a function of time (Doc. 2).

5.1) Referring to document 2, indicate the values of T_0 and x_0.



Doc. 2

5.2) Deduce the value of k.
5.3) Prove that the mechanical energy of the system (Oscillator - Earth) is $ME = 6.25\times10^{-2}$ J.
5.4) Using document 2, indicate an instant at which the elastic potential energy of the spring is zero.
5.5) Determine the maximum speed attained by G.

Exercise 2 (6 pts)

Studying the motion of an object

Consider:

- a rail AOB located in a vertical plane composed of two straight parts: a horizontal part AO and an inclined part OB making an angle $\alpha = 30^0$ with the horizontal;
- two objects (S_1) and (S_2) taken as particles of same mass m = 80 g;
- a massless spring (R), of force constant k = 200 N/m and natural length ℓ_0, fixed from one of its ends to a support at A with the other end free.

Take:

- the horizontal plane containing O as the reference level for gravitational potential energy;
- $g = 10\ m/s^2$.

1) Launching particle (S_1)

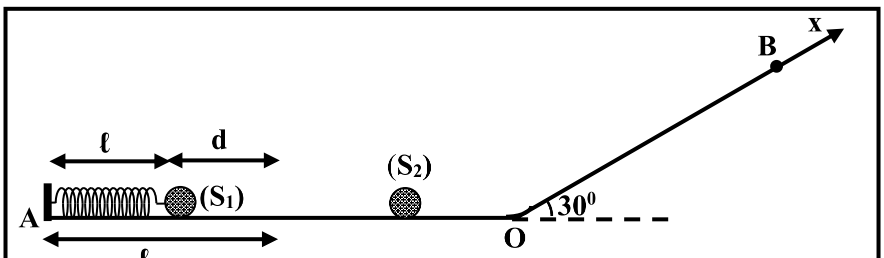
In order to launch (S_1), it is placed against the free end of the spring, the spring is compressed by a distance d, and then the system [Spring - (S_1)] is released from rest (Doc.3).

When the spring returns to its natural length ℓ_0, (S_1) leaves the spring with a velocity $\vec{V}_1$ parallel to AO .

After launching, (S_1) moving with the velocity $\vec{V}_1$, collides head-on with (S_2) which is placed initially at rest on the rail AO.

Just after the collision, (S_1) stops and (S_2) moves with a velocity $\vec{V}_2$ parallel to AO and of magnitude $V_2 = 5$ m/s.

(S_1) and (S_2) move without friction on the rail AO.



Doc. 3

1.1) Apply the law of conservation of linear momentum to show that the magnitude of $\vec{V}_1$ is $V_1 = 5$ m/s.

1.2) Deduce that the collision between (S_1) and (S_2) is elastic.

1.3) Determine the value of d.

2) Motion of (S_2) on the inclined part OB

At the instant $t_0 = 0$, (S_2) starts from O on the inclined part OB with a velocity $\vec{V}_0 = V_0\ \vec{i} = 5\ \vec{i}$ (m/s), where $\vec{i}$ is the unit vector along the x-axis parallel to OB. On this part, (S_2) is submitted to a friction force $\vec{f}$ of constant magnitude f and of direction opposite to its motion.

2.1) Name the external forces acting on (S_2) during its motion along the track OB.

2.2) Show that the sum of the external forces acting on (S_2) during its upward motion along OB is: $\Sigma\vec{F} = -(f + mg\sin\alpha)\ \vec{i}$.

2.3) The expression of the linear momentum of (S_2) during its upward motion along OB is: $\vec{P} = (-0.9\ t + 0.4)\ \vec{i}$ (SI).

Knowing that $\dfrac{d\vec{P}}{dt} = \Sigma\vec{F}$, determine f.

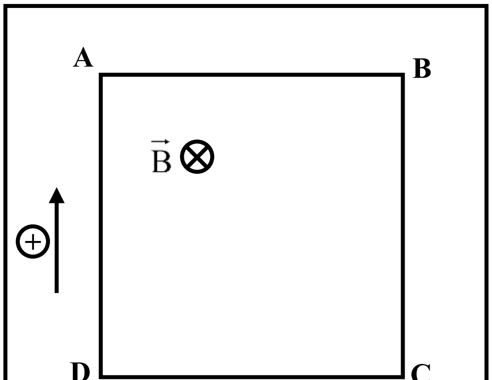
Exercise 3 (7 pts)

Electromagnetic induction

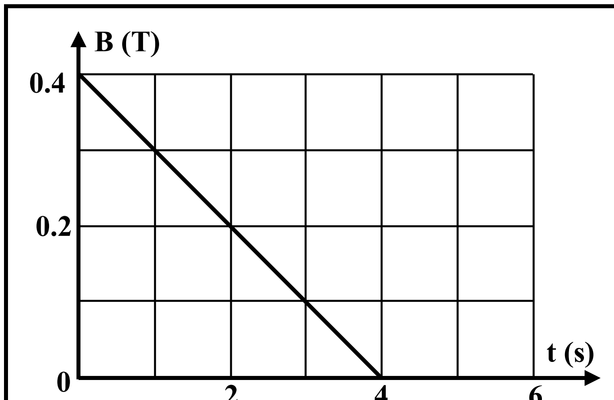
The aim of this exercise is to determine the direction of the induced current in a square-shaped loop by two methods.

For this aim, consider a square-shaped loop ABCD, of side a = 10 cm and resistance r = 2 Ω, is placed in a uniform magnetic field $\vec{B}$, whose magnitude varies with time. The direction of $\vec{B}$ is perpendicular to the plane of the loop (Doc. 4).

Document 5 shows, during the time interval [0, 4 s], the magnitude B of $\vec{B}$ as a function of time.



Doc. 4



Doc. 5

1) An induced current flows in the loop during the time interval [0, 4 s]. Justify.

2) Apply Lenz's law to specify the direction of the induced current in the loop.

3) Prove that the expression of B during the time interval [0, 4 s] is: $B = -0.1t + 0.4$ (SI).

4) Take into consideration the chosen positive direction indicated on document 4, determine, as a function of time, the expression of the magnetic flux crossing the loop.

5) Deduce the value of the induced electromotive force « e ».

6) The induced current in the loop is given by $i = \frac{e}{r}$. Deduce the value and the direction of i.

7) Compare the direction of the induced current obtained in part 6 with that obtained in part 2.

مسابقة في مادة الفيزياء
أسس التصحيح

Exercise 1 (7 pts) Mechanical oscillations

Part		Answer	Mark
1		Friction is negligible, then the mechanical energy of the system is conserved. (Or the sum of the works done by the non-conservative forces is zero, then the mechanical energy is conserved).	0.25
2		$ME = KE + EPE = \frac{1}{2} m v^2 + \frac{1}{2} kx^2$	0.5
3		ME = constant , then $\frac{dME}{dt} = 0$, so $m v v' + k x x' = 0$, hence $v (m x'' + k x) = 0$ v = 0 is rejected , then $x'' + \frac{k}{m} x = 0$	1
4		The differential equation is of the form: $x'' + \omega_o^2 x = 0$, with $\omega_o = \sqrt{\frac{k}{m}}$ $T_0 = \frac{2\pi}{\omega_o}$; therefore, $T_0 = 2\pi\sqrt{\frac{m}{k}}$	1.5
5	5.1	$T_0 = 0.2$ s and $x_0 = 5$ cm	1
	5.2	$0.2 = 2\pi\sqrt{\frac{0.05}{k}}$ k = 50 N/m	1
	5.3	When the speed is zero, the elongation is maximum, then: $ME = KE + EPE = 0 + EPE = \frac{1}{2} kX^2_{max}$ $ME = 0.5 \times 50 \times 0.05^2 = 0.0625\ J = 6.25 \times 10^{-2}\ J$	0.75
	5.4	t = 0.05 s **or** t = 0.15 s **or** t = 0.25 s **…..**	0.25
	5.5	When G passes through O, its speed is maximum. Then: $ME = KE + EPE = KE + 0 = \frac{1}{2} mV^2_{max}$ $0.0625 = 0.5 \times 0.05 \times (V)_{max}^2$; therefore, $V_{max} = 1.58$ m/s	0.75

Exercise 2 (6 pts) Study the motion of an object

Part		Answer	Mark
1	1.1	$\vec{P}_{J.B.C} = \vec{P}_{J.A.C}$ $m\vec{V}_1 + \vec{0} = \vec{0} + m\vec{V}_2$, $\vec{V}_1 = \vec{V}_2$ then, $V_1 = 5$ m/s	1.5
	1.2	System [(S_1), (S_1)] The collision is elastic if $KE_{system(before)} = KE_{system(after)}$ $KE_{(before)} = KE_{(S1)} + KE_{(S2)} = \frac{1}{2}mV_1^2 + 0 = \frac{1}{2} \times 0.08 \times 5^2 + 0 = 1$ J $KE_{(after)} = KE_{(S1)} + KE_{(S2)} = 0 + \frac{1}{2}mV_2^2 = 0 + \frac{1}{2} \times 0.08 \times 5^2 = 1$ J Therefore, the collision is elastic.	1
	1.3	Apply the law of conservation of mechanical energy of the system [Oscillator- Earth] $ME_{(R) \text{ is compressed by } d} = ME_{(R) \text{ is in its initial length}}$, $(KE + GPE + EPE)_{(R) \text{ is compressed by } d} = (KE + GPE + EPE)_{(R) \text{ is in its initial length}}$ $0 + \frac{1}{2}kd^2 + 0 = \frac{1}{2}mV_1^2 + 0 + 0$, $\frac{1}{2} \times 200 \times d^2 = \frac{1}{2} \times 0.08 \times 5^2$ then d = 0.1 m = 10 cm	1.5
2	2.1	The forces acting on (S_2) on OB are: $m\vec{g}$: its weight, $\vec{N}$: Normal reaction $\vec{f}$: friction	0.75
	2.2	$\Sigma\vec{F} = m\vec{g} + \vec{N} + \vec{f}$, Component along the direction $\overrightarrow{Ox}$: $\Sigma\vec{F} = -mg\sin\alpha\,\vec{i} + 0\,\vec{i} - f\,\vec{i}$ $\Sigma\vec{F} = -(f + mg\sin\alpha)\vec{i}$ Or : $\Sigma\vec{F} = m\vec{g} + \vec{N} + \vec{f} = -mg\sin\alpha\,\vec{i} + mg\cos\alpha\,\vec{j} - N\,\vec{j} - f\,\vec{i}$ But : $mg\cos\alpha\,\vec{j} - N\,\vec{j} = 0$, then, $\Sigma\vec{F} = -(f + mg\sin\alpha)\vec{i}$	0.75
	2.3	$\frac{d\vec{P}}{dt} = \Sigma\vec{F}$, $-0.9\,\vec{i} = -(f + mg\sin\alpha)\vec{i}$ $-0.9 = -f - 0.08 \times 10 \times 0.5$ Therefore, f = 0.5 N	0.5

Exercise 3 (7 pts) **Electromagnetic induction**

Part	Answer	Mark
1	During the interval [0 s, 4 s], B varies with time, then the magnetic flux varies with time, therefore an emf (e) is induced in the circuit. The circuit is closed, then a current is induced in the circuit.	**1**
2	During the interval [0 s, 4 s], B decreases with time, then the direction of the induced magnetic field as that of $\vec{B}$ to oppose this decrease (Lenz's law). Using the right hand rule, the induced current flows in the loop in the positive direction (clockwise).	**1**
3	In the interval [0s, 4s], B(t) varies linearly with time : B = at + b a = slope = $\frac{0-0,4}{4-0} = -0,1$ T/s $0 = -0.1\times 4 + b$ b = 0.4 T then B = - 0.1t + 0.4	**1**
4	$\phi = BS\cos(\vec{B}\ \vec{n}) = (-0.1t + 0.4)\times(0.1)^2\times\cos(0)$ $\phi = -10^{-3}\,t + 4\times10^{-3}$ (SI)	**1**
5	$e = -\frac{d\phi}{dt} = 10^{-3}$ V	**1**
6	$i = \frac{e}{r} = \frac{10^{-3}}{2} = 0.5\times10^{-3}$A i > 0 , then the induced current flows in the positive direction (clockwise).	**1.5**
7	The are the same.	**0.5**

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المدة: ساعة ونصف	الرقم:

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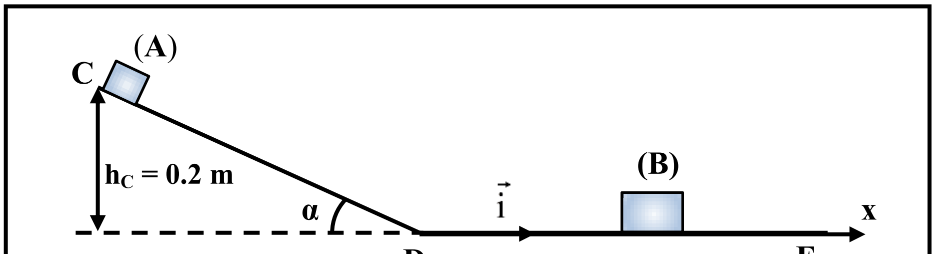
Exercise 1 (6 pts.)

Verification of the principle of interaction

The aim of this exercise is to verify the principle of interaction between two blocks.
For this purpose, we consider two blocks (A) and (B) considered as particles of respective masses $m_A = 200$ g and $m_B = 800$ g.
(A) and (B) can move without friction on a track CDE lying in a vertical plane.
This track is formed of two parts: the first one CD is straight and inclined by an angle α with respect to the horizontal and the second one DE is straight and horizontal.
Block (A) is released without initial velocity from point C situated at a height $h_C = 0.2$ m above a horizontal x-axis, confounded with DE, of unit vector $\vec{i}$ (Doc. 1).
Take:

- the horizontal plane containing the x-axis as a reference level for gravitational potential energy;
- $g = 10$ m/s^2.



Doc. 1

1) The mechanical energy of the system [(A), Track, Earth] is conserved between C and D. Why?

2) Deduce that the speed of (A) at point D is $V_A = 2$ m/s.

3) (A) continues its motion with a velocity $\overrightarrow{V_A} = 2\,\vec{i}$ (m/s) along track DE until it makes a head-on elastic collision with (B) initially at rest.

Show that the velocities of (A) and (B) right after the collision are $\overrightarrow{V'_A} = -1.2\,\vec{i}$ (m/s) and $\overrightarrow{V'_B} = 0.8\,\vec{i}$ (m/s) respectively.

4) The duration of the collision is $\Delta t = 0.1$ s, so $\frac{\Delta\vec{P}}{\Delta t} \cong \frac{d\vec{P}}{dt}$.

Apply, during Δt, Newton's second law:

4.1) on (B) to determine the force $\vec{F}_{A/B}$ exerted by (A) on (B);

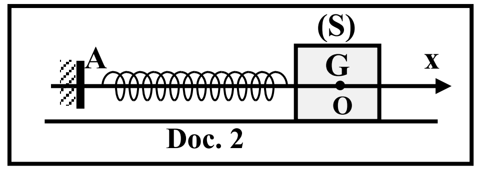
4.2) on (A) to determine the force $\vec{F}_{B/A}$ exerted by (B) on (A).

5) Deduce that the principle of interaction is verified.

Exercise 2 (7 pts.)

Mechanical oscillations

A mechanical oscillator is formed of a block (S) of mass m and a horizontal light spring of force constant k = 100 N/m.
The spring is connected from one of its ends to a fixed support A.
(S) is attached to the other end of the spring and it may slide without friction on a horizontal surface (Doc. 2).



At equilibrium, the center of mass (G) of (S) coincides with the origin O of the x-axis.

At an instant $t_0 = 0$, (G) is at O and (S) is launched, in the negative direction, with an initial velocity $\overrightarrow{V_0}$.
(G) thus performs mechanical oscillations.

At an instant t, the abscissa of (G) is $x = \overline{OG}$ and the algebraic value of its velocity is $v = x' = \dfrac{dx}{dt}$.

The curve of document 3 represents, as a function of time, one of these three forms of energy: the kinetic energy, the elastic potential energy, or the mechanical energy of the system (Oscillator, Earth).

The aim of this exercise is to determine the value of m and the time equation of (G).

Take the horizontal plane containing (G) as a reference level for gravitational potential energy.

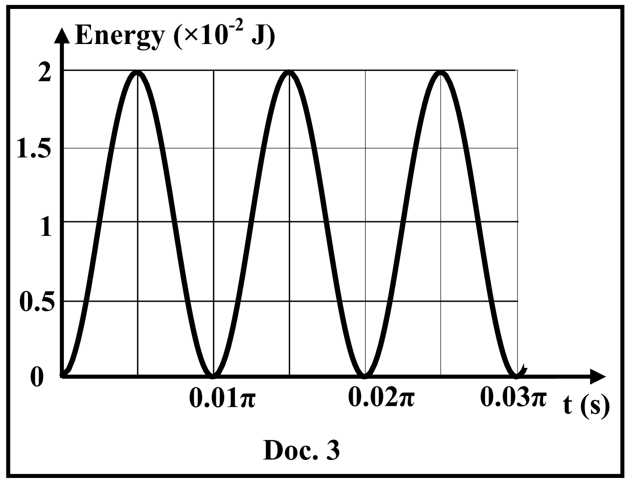
1) Specify the type of the oscillations of (G).

2) The curve of document 3 represents the elastic potential energy of the system (Oscillator, Earth) as a function of time. Why?

3) Use document 3 to answer the following questions:

3.1) Calculate the amplitude X_m of the oscillations of (G).

3.2) Knowing that the period T_{energy} of the elastic potential energy of the above system is half the proper (natural) period T_0 of oscillations of (G) $\left(T_{energy} = \dfrac{T_0}{2}\right)$, calculate T_0.



4) The time equation of the motion of (G) is given by: $x = X_m \sin(\omega_0 t + \varphi)$, where φ is constant and ω_0 is the proper (natural) angular frequency of the oscillator.

4.1) Determine the value of φ.

4.2) Calculate the value of ω_0.

4.3) Deduce the expression of x as a function of time.

5) Knowing that $\omega_0 = \sqrt{\dfrac{k}{m}}$, calculate the value of m.

Exercise 3 (7 pts)

Brightness of a lamp

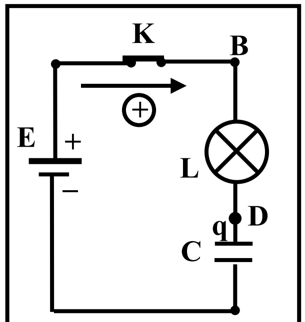
The aim of this exercise is to study the brightness of a lamp in two experiments.
For this purpose, consider:

- an ideal battery of electromotive force E = 9 V;
- a lamp L acting as a resistor of resistance R = 10 Ω;
- a capacitor of capacitance C = 0.1 F;
- a switch K.

Given that the brightness of the lamp increases with the increase of the current it carries and vice-versa.

1) First experiment: charging the capacitor

We connect the capacitor, initially uncharged, in series with the lamp and switch K across the battery (Doc. 4).
Switch K is closed at $t_0 = 0$, and the capacitor starts charging.



Doc. 4

1.1) Show that the differential equation that governs the variation of the voltage, $u_{DA} = u_C$, across the capacitor is: $E = RC\,\frac{du_C}{dt} + u_C$.

1.2) The solution of the obtained differential equation is of the form:

$u_C = E\left(1 - e^{\frac{-t}{\tau}}\right)$, where τ is constant.

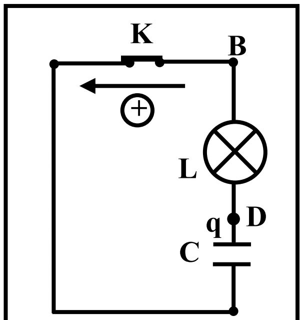
1.2.1) Determine the expression of τ in terms of R and C.

1.2.2) Calculate τ.

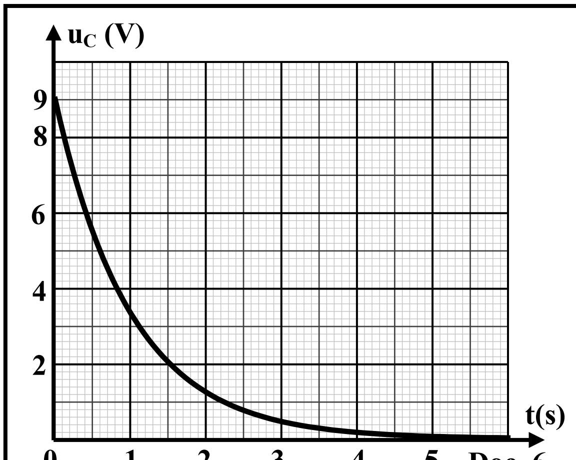
1.3) Deduce that the expression of the charge current is $i = 0.9\ e^{-t}$ (SI).

2) Second experiment: discharging the capacitor

The fully charged capacitor is connected in series with the lamp and switch K.
We close K at $t_0 = 0$ taken as a new initial time.
The capacitor discharges through the lamp (Doc. 5).
Document 6 shows the voltage $u_{DA} = u_C$ as a function of time.



Doc. 5



Doc. 6

2.1) Use document 6 to determine the value of the time constant τ' of this RC circuit.

2.2) Given that $u_C = E\ e^{\frac{-t}{\tau'}}$. Deduce the expression of the discharge current as a function of time.

3) Conclusion

Using parts **(1.3)** and **(2.2)**, describe the brightness of the lamp in the first and the second experiments during the time interval [0 , 5 s]. Justify your answer.

مسابقة في مادة الفيزياء
أسس التصحيح - إنكليزي

Exercise 1 (6 pts) — Verification of the principle of interaction

Part		Answer	Mark
1		Friction is neglected or the sum of the works done by the non-conservative forces is zero, therefore the mechanical energy is conserved.	0.5
2		ME is conserved, then $ME_C = ME_D$ $KE_C + GPE_C = KE_D + GPE_D$; ($V_C = 0$, then $KE_C = 0$ and $h_D = 0$, so $GPE_D = 0$) $0 + m_A g h_C = \frac{1}{2} m_A V_A^2 + 0$, then $V_A = \sqrt{2gh} = \sqrt{(2)(10)(0.2)} = 2$ m/s	1.5
3		During the collision, linear momentum is conserved: $\vec{P}_{before} = \vec{P}_{after}$ $m_A \vec{V}_A = m_A \vec{V}'_A + m_B \vec{V}'_B$ This is a head-on collision, then the velocities are collinear, so we can write the equation in the algebraic form: $m_A V_A = m_A V'_A + m_B V'_B$ $m_A (V_A - V'_A) = m_B V'_B$ ….**(equation 1)** The collision is elastic, then the kinetic energy is conserved: $KE_{before} = KE_{after}$ $\frac{1}{2} m_A V_A^2 = \frac{1}{2} m_A V'^2_A + \frac{1}{2} m_B V'^2_B$, then $m_A (V_A^2 - V'^2_A) = m_B V'^2_B$ $m_A(V_A - V'_A)(V_A + V'_A) = m_B V'^2_B$ **(equation 2)** $\frac{\text{equation 2}}{\text{equaiton 1}}$: $V_A + V'_A = V'_B$ **(equation 3)** Replace V'_B in equation 1 by its expression in equation 2: $V'_A = \frac{m_A - m_B}{m_A + m_B} V_A$ $V'_A = \frac{0.2 - 0.6}{0.2 + 0.8} \times 2 = -1.2$m/s , hence $\vec{V}'_A = V'_A \vec{i} = -1.2 \vec{i}$ (m/s) Equation 3 : $V'_B = V'_A + V_A = -1.2 + 2 = 0.8$ m/s , so $\vec{V}'_B = V'_B \vec{i} = 0.8 \vec{i}$ (m/s) **<u>Or</u>** :$V'_B = \frac{2m_A}{m_A + m_B} V_A = \frac{2\ (0.2)}{0.2 + 0.8} \times 2 = 0.8$ m/s , so $\vec{V}'_B = V'_B \vec{i} = 0.8 \vec{i}$ (m/s)	2
4	4.1	Newton's 2nd law on (B): $\Sigma \vec{F}_{ext} = \frac{d\vec{P}_B}{dt}$, then $m_B \vec{g} + \vec{N}_B + \vec{F}_{A/B} = \frac{\Delta \vec{P}_B}{\Delta t}$; $m\vec{g} + \vec{N} = \vec{0}$ $\vec{F}_{A/B} = \frac{m_B \vec{V}'_B - m_B \vec{V}_B}{\Delta t} = \frac{0.8 \times 0.8 \vec{i} - \vec{0}}{0.1} = 6.4 \vec{i}$ (N)	1
	4.2	Newton's 2nd law on (A): $\Sigma \vec{F}_{ext} = \frac{d\vec{P}_A}{dt}$, then $m_A \vec{g} + \vec{N}_A + \vec{F}_{B/A} = \frac{\Delta \vec{P}_A}{\Delta t}$ $\vec{F}_{B/A} = \frac{m_A \vec{V}'_A - m_A \vec{V}_A}{\Delta t} = \frac{0.2\ (-1.2\ \vec{i}) - 0.2\ (-2\ \vec{i})}{0.1} = -6.4 \vec{i}$ (N)	0.5
5		$\vec{F}_{A/B} = -\vec{F}_{B/A}$, then the principle of interaction is verified.	0.5

Exercise 2 (7pts) **Mechanical Oscillations**

Part		Answer	Mark
1		(S) moves without friction, then the type of oscillation is free undamped mechanical oscillation.	1
2		At $t_o = 0$, (G) is at O, then $x = 0$; hence $EPE_o = \frac{1}{2}kx^2 = 0$. Or: At $t_o = 0$, $V_o \neq 0$, then $KE_o \neq 0$. Also, $ME \neq 0$ at all instants. So, this curve does not represent KE and ME; therefore, the curve represents EPE versus time.	0.5
3	3.1	EPE is maximum when $x = X_m$, then $EPE_{max} = \frac{1}{2} k X_m^2$ $2\times10^{-2} = \frac{1}{2}(100) X_m^2$, then $X_m = 0.02$ m	1
	3.2	Graphically: $T_{energy} = 0.01\,\pi$ (s) $T_{energy} = \frac{T_0}{2}$, then $T_0 = 2\,T_{energy} = 2 \times 0.01\,\pi = 0.02\pi$ s	0.75
4	4.1	$x = X_m \sin(\omega_0 t + \varphi)$ At $t_0 = 0$: $x_0 = 0$; $0.02 \sin(\varphi) = 0$, then $\varphi = 0$ or $\varphi = \pi$ rad $v = \omega_0 X_m \cos(\omega_0 t + \varphi)$ $V_o = \omega_0 X_m \cos(\varphi)$ At $t_0 = 0$: $V_o < 0$ [(S) is launched in the negative direction] But, $\omega_0 X_m > 0$, then $\cos(\varphi) < 0$ Therefore, the acceptable value is $\varphi = \pi$ rad.	1.5
	4.2	$\omega_0 = \frac{2\pi}{T_0} = \frac{2\pi}{0.02\pi} = 100$ rad/s.	0.75
	4.3	$x = 0.02 \sin(100\,t + \pi)$, with x in (m) and t in (s)	0.5
5		$\omega_0 = \sqrt{\frac{k}{m}}$, then $\omega_0^2 = \frac{k}{m}$, so $m = \frac{k}{\omega_0^2} = \frac{100}{100^2} = 0.01$ kg	1

Exercise 3 (7 pts) **Brightness of a lamp**

Part		Answer	Mark
1	1.1	$u_{BA} = u_{BD} + u_{DA}$, then $E = Ri + u_C$ $i = \frac{dq}{dt} = C\frac{du_C}{dt}$ Then , $E = RC\frac{du_C}{dt} + u_C$	1
	1.2.1	$u_C = E(1 - e^{\frac{-t}{\tau}}) = E - E\,e^{-\frac{t}{\tau}}$, then $\frac{du_C}{dt} = \frac{E}{\tau}\,e^{\frac{-t}{\tau}}$ Replacing u_C and $\frac{du_C}{dt}$ by their expressions in the differential equation, gives: $E = RC\,\frac{E}{\tau}\,e^{\frac{-t}{\tau}} + E - E\,e^{\frac{-t}{\tau}}$, then $E\,e^{\frac{-t}{\tau}}(\frac{RC}{\tau} - 1) = 0$ $E\,e^{\frac{-t}{\tau}} = 0$ is rejected Then, $(\frac{RC}{\tau} - 1) = 0$; therefore, $\tau = RC$	1.5
	1.2.2	$\tau = RC = 10 \times 0.1$, then $\tau = 1$ s	0.5
	1.3	$i = C\frac{du_C}{dt}$, then $i = C\,\frac{E}{\tau}\,e^{\frac{-t}{\tau}} = \frac{CE}{RC}\,e^{\frac{-t}{\tau}} = \frac{E}{R}\,e^{-\frac{t}{\tau}}$ $i = \frac{9}{10}\,e^{-\frac{t}{1}}$, so $i = 0.9\,e^{-t}$ SI	1
2	2.1	At $t = \tau'$; $u_C = 0.37 \times u_{C_{maximum}} = 0.37 \times 9 = 3.33$ V. Graphically, $u_C = 3.33$ V at $t = 1$ s , then $\tau' = 1$ s	1
	2.2	$i = -\frac{dq}{dt} = -C\frac{du_C}{dt} = C\,\frac{E}{\tau'}\,e^{-\frac{t}{\tau'}}$ Then, $i = 0.1 \times \frac{9}{1}e^{-\frac{t}{1}} = 0.9\,e^{-t}$	1
3		In both experiments, $i = 0.9e^{-t}$, then the current decreases with time; therefore, the brightness of the lamp decreases. **<u>Or:</u>** Experiment 1 : $i = 0.9e^{-t}$; For $t = 0$, $i = 0.9$A and for $t = 5$ s, $i \cong 0$. Then, the current decreases with time; therefore, the brightness of the lamp decreases. Same explanation in experiment 2.	1

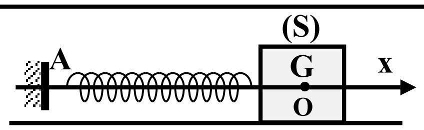
مسابقة في مادة الفيزياء	الاسم:
المدة: ساعة ونصف	الرقم:

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

Exercise 1 (7 pts)

Mechanical oscillations

A mechanical oscillator consists of a block (S) of mass m and a spring of negligible mass and force constant k = 20 N/m.
The spring is connected from one of its ends to a fixed support A.
(S) is attached to the other end of the spring and it may slide without friction on a horizontal support (Doc. 1).



Doc. 1

At equilibrium, G, the center of mass of (S), coincides with the origin O of the x-axis.
At the instant $t_0 = 0$, G is at O and we launch (S) with a velocity $\vec{v}_0 = v_0\,\vec{i}$; thus, (S) undergoes mechanical oscillations with an amplitude X_m.
At an instant t, the abscissa of G is $x = \overline{OG}$ and the algebraic value of its velocity is $v = x' = \frac{dx}{dt}$.
The aim of this exercise is to study for this oscillator the effect of v_0 on the oscillation amplitude X_m.
Take:

- the horizontal plane passing through G as a reference level for gravitational potential energy;
- $g = 10\ m/s^2$ and $\pi^2 = 10$.

1) Theoretical study

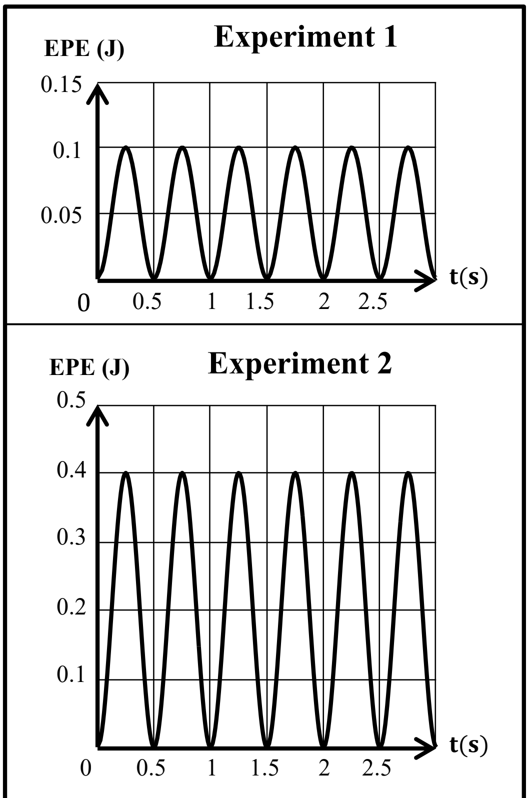
1.1) Write the expression of the mechanical energy ME of the system (Oscillator , Earth) in terms of x, m, k and v.

1.2) Determine the second order differential equation that governs the variation of x.

1.3) Deduce the expression of the proper (natural) period T_0 of the oscillations in terms of m and k.

2) Experimental study

An appropriate device gives the elastic potential energy EPE of the oscillator as a function of time for two different experiments, experiment 1 and experiment 2 (Doc. 2).



Doc. 2

2.1) Use the graphs of document 2 in order to:

2.1.1) justify that the oscillations of (S) are undamped.

2.1.2) copy and then complete the following table:

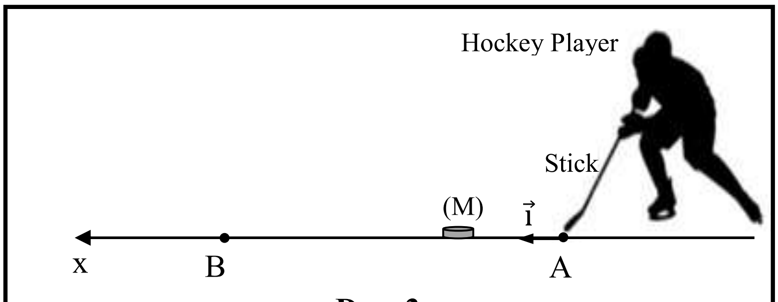
	Experiment 1	Experiment 2
The maximum value of EPE		
The value of the period T_E of EPE		

2.2) Show that m = 0.5 kg knowing that $T_0 = 2T_E$.
2.3) Show that $X_{m(2)} = 2\ X_{m(1)}$, where $X_{m(1)}$ and $X_{m(2)}$ are the amplitudes of the oscillations in experiments 1 and 2 respectively.
2.4) Determine the values of v_0 for the two experiments.
2.5) Deduce whether X_m increases, decreases, or remains the same as v_0 increases.

Exercise 2 (6.5 pts)

Motion of a hockey puck

The purpose of this exercise is to study the motion of a hockey puck (M).
(M), taken as a particle of mass m = 170 g, can slide on a horizontal ice rink. A hockey player hits puck (M) with his stick from point A (Doc. 3).
Take the horizontal plane passing through (M) as a reference level for gravitational potential energy.



Doc. 3

1) The collision between (M) and the stick occurs in a very short time. Choose the correct sentence out of the three following sentences.
Sentence 1: During this collision, the linear momentum and the kinetic energy of the system [Stick , (M)] are necessarily conserved.
Sentence 2: During this collision, the linear momentum of the system [Stick , (M)] is conserved but the kinetic energy of this system is not necessarily conserved.
Sentence 3: During this collision, the linear momentum of the system [Stick , (M)] is not necessarily conserved but the kinetic energy of this system is necessarily conserved.

2) Just after the collision, (M) is launched from point A with a velocity $\vec{v}_A = 18\ \vec{i}$ (m/s). Puck (M) moves on the ice rink along an x-axis, and it stops at point B after travelling a distance AB = 54 m during a time Δt (Doc. 3).

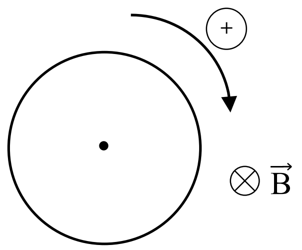
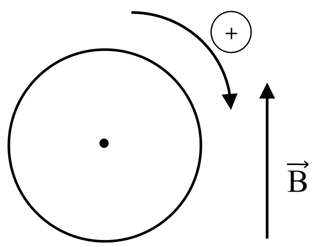
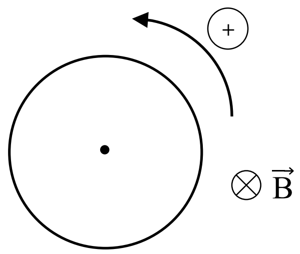
2.1) Calculate the mechanical energy of the system [(M) , Earth] at A and then at B.
2.2) Deduce that (M) is submitted to a friction force $\vec{f}$ during its motion between A and B.
2.3) Given that the value f of $\vec{f}$ is constant. Deduce that f = 0.51 N.
2.4) Name the external forces acting on (M) between A and B, and then draw, not to scale, a diagram for these forces.
2.5) Show that the sum of these forces is $\sum \vec{F}_{ext} = -\ 0.51\ \vec{i}$ (N).
2.6) Determine the linear momenta of (M), « $\vec{P}_A$ » at point A and « $\vec{P}_B$ » at point B.
2.7) Deduce the variation $\Delta\vec{P}$ of the linear momentum of (M) during Δt.
2.8) Calculate Δt knowing that $\Delta\vec{P} = (\sum \vec{F}_{ext})\ \Delta t$.

Exercise 3 (6.5 pts)

Electromagnetic induction

The purpose of this exercise is to determine the direction of the induced current in a circular loop by two different methods.
Consider a circular conducting loop of radius r = 10 cm and resistance R = 2 Ω. The loop is placed in a uniform magnetic field $\vec{B}$.

1) Document 4 shows three different cases.

1^{st} case	2^{nd} case	3^{rd} case
The plane of the loop is perpendicular to the magnetic field lines of $\vec{B}$.	The plane of the loop is parallel to the magnetic field lines of $\vec{B}$.	The plane of the loop is perpendicular to the magnetic field lines of $\vec{B}$.
		
Doc. 4		

Match each of the following sentences 1, 2 and 3 to its appropriate case. Justify.

Sentence 1: The magnetic flux through the loop is zero.
Sentence 2: The magnetic flux through the loop is positive.
Sentence 3: The magnetic flux through the loop is negative.

2) Consider the first case of document 4. During the time interval [0 , 2 s], the value B of the magnetic field $\vec{B}$ decreases with time according to the relation:

$$B = -0.04\,t + 0.8 \quad \text{(SI)}$$

2.1) A current is induced in the loop during the time interval [0 , 2s]. Justify.
2.2) Apply Lenz's law in order to specify the direction of the induced current.
2.3) Determine the expression of the magnetic flux crossing the loop as a function of time.
2.4) Deduce the value of the induced electromotive force « e ».
2.5) The current carried by the loop is given by the relation $i = \dfrac{e}{R}$. Deduce the value and the direction of « i ».
2.6) Compare the direction of the induced current obtained in part (2.5) to that obtained in part (2.2).

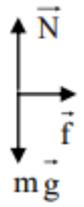
وزارة التربية والتعليم العالي
المديرية العامّة للتربية
دائرة الامتحانات الرسميّة

امتحانات الشهادة الثانوية العامة
فرع علوم الحياة

دورة العام 2022 الإستثنائية

مسابقة في مادة الفيزياء — الاسم:
المدة: ساعة ونصف — الرقم:

<table>
<tr><th colspan="5">Exercise 1 : Mechanical oscillations (7 pts)</th></tr>
<tr><th colspan="3">Part</th><th>Answer</th><th>Mark</th></tr>
<tr><td rowspan="3">1</td><td colspan="2">1.1</td><td>ME = KE + EPE = $\frac{1}{2}$ m v^2 + $\frac{1}{2}$ k x^2</td><td>0.5</td></tr>
<tr><td colspan="2">1.2</td><td>Friction is neglected, then the mechanical energy is conserved. Or: The sum of the works done by the nonconservative forces is zero, then ME is conserved.
Then, $\frac{dME}{dt} = 0$, so m v v' + k x x' = 0 { v = x' and v' = x" }
v (m x" + k x) = 0 , but v = 0 is rejected , so m x" + k x = 0 ; therefore, x" + $\frac{k}{m}$ x = 0</td><td>1</td></tr>
<tr><td colspan="2">1.3</td><td>The differential equation is of the form: x" + $\omega_0^2 x = 0$ with $\omega_0 = \sqrt{\frac{k}{m}}$
$T_0 = \frac{2\pi}{\omega_0}$, then $T_0 = 2\pi\sqrt{\frac{m}{k}}$</td><td>1</td></tr>
<tr><td rowspan="6">2</td><td rowspan="2">2.1</td><td>1</td><td>$EPE_{max} = \frac{1}{2}$ k X_m^2 = constant.
k is constant, then X_m is constant; therefore, the oscillations are undamped.</td><td>0.5</td></tr>
<tr><td>2</td><td><table><tr><th></th><th>Experiment 1</th><th>Experiment 2</th></tr><tr><td>The maximum value of EPE</td><td>0.1 J</td><td>0.4 J</td></tr><tr><td>The value of the period T_E of EPE</td><td>0.5 s</td><td>0.5 s</td></tr></table></td><td>0.5
0.5</td></tr>
<tr><td colspan="2">2.2</td><td>$T_0 = 2\ T_E = 2\ (0.5) = 1$ s
$T_0 = 2\pi\sqrt{\frac{m}{k}}$, then $T_0^2 = 4\pi^2 \frac{m}{K}$, so $m = \frac{k\,T_0^2}{4\pi^2}$
$m = \frac{20 \times 1}{4 \times 10}$, hence m = 0.5 kg</td><td>0.5</td></tr>
<tr><td colspan="2">2.3</td><td>Experiment 1 : $EPE_{max} = 0.1 = \frac{1}{2}$ k $X_{m(1)}^2$ … eq(1)
Experiment 2 : $EPE_{max} = 0.4 = \frac{1}{2}$ k $X_{m(2)}^2$ …eq(2) ; Dividing eq(2) by eq(1) gives:
$\frac{0.4}{0.1} = \frac{X_{m(2)}^2}{X_{m(1)}^2}$, then $4 = (\frac{X_{m(2)}}{X_{m(1)}})^2$, hence $2 = \frac{X_{m(2)}}{X_{m(1)}}$
Therefore, $X_{m(2)} = 2\ X_{m(1)}$</td><td>0.5</td></tr>
<tr><td colspan="2">2.4</td><td>ME = constant , then ME = EPE_{max} = KE_{max} , so $EPE_{max} = \frac{1}{2}$ m v_0^2
Experiment 1 : $0.1 = \frac{1}{2}$ (0.5) $v_{0(1)}^2$, then $v_{0(1)}$ = 0.63 m/s
Experiment 2 : $0.4 = \frac{1}{2}$ (0.5) $v_{0(2)}^2$, then $v_{0(2)}$ = 1.26 m/s</td><td>0.5
0.25
0.25</td></tr>
<tr><td colspan="2">2.5</td><td>v_o in experiment 2 is greater than v_o in experiment 1 ($v_{0(2)} > v_{0(1)}$) and $X_{m(2)} > 2\ X_{m(1)}$; therefore, as v_0 increases X_m increases.</td><td>0.5
0.5</td></tr>
</table>

Exercise 2: Motion of a hockey puck (6.5 pts)			
Part		**Answer**	**Mark**
1		Sentence 2	**0.5**
2	**2.1**	$GPE_A = GPE_B = 0$ since (M) is at the reference level. $ME_A = KE_A + GPE_A = \frac{1}{2}\,m\,v_A^2 + 0 = \frac{1}{2} \times 0.17 \times 18^2$, then $ME_A = 27.54$ J $KE_B = 0$ since (M) stops at point B. $ME_B = KE_B + GPE_B = 0 + 0$, then $ME_B = 0$	**0.75** **0.25**
	2.2	$ME_B < ME_A$, then (M) is submitted to a friction force.	**0.25**
	2.3	$\Delta ME = W_{\vec{f}} = \vec{f}\,.\,\overrightarrow{AB}$, then $ME_B - ME_A = -\,f \times AB$ $0 - 27.54 = -\,f \times 54$, hence $f = 0.51$ N	**1**
	2.4	Forces acting on (M) : The weight $m\vec{g}$ The normal force $\vec{N}$ exerted by the ice rink The friction force $\vec{f}$ 	**0.5** **0.5**
	2.5	$\sum \vec{F}_{ext} = m\vec{g} + \vec{N} + \vec{f}$, but $m\vec{g} + \vec{N} = \vec{0}$ Then, $\sum \vec{F}_{ext} = \vec{f} = -f\,\vec{i} = -\,0.51\,\vec{i}$ (N)	**0.75**
	2.6	$\vec{P}_A = m\,\vec{v}_A = 0.17 \times 18\,\vec{i}$, then $\vec{P}_A = 3.06\,\vec{i}$ (kg.m/s) $\vec{P}_B = m\,\vec{v}_B = m\,(\vec{0})$, then $\vec{P}_B = \vec{0}$	**0.75** **0.25**
	2.7	$\Delta\vec{P} = \vec{P}_B - \vec{P}_A = \vec{0} - 3.06\,\vec{i}$, then $\Delta\vec{P} = -\,3.06\,\vec{i}$ (kg.m/s)	**0.5**
	2.8	$\Delta t = \frac{\Delta\vec{P}}{\sum \vec{F}_{ext}} = \frac{-\,3.06\,\vec{i}}{-\,0.51\,\vec{i}}$, then $\Delta t = 6$ s	**0.5**

Exercise 3 (6.5 pts)	Electromagnetic induction	
Part	**Answer**	**Mark**
1	Sentence 1 corresponds to the 2nd case, because: • $\phi = \vec{B} \cdot \vec{n}\, S = B\, S \cos(\vec{B}, \vec{n}) = B\, S \cos 90^o = 0$ • **or** the plane of the loop is parallel to the field lines • **or** the field lines do not cross the loop Sentence 2 corresponds to the 1nd case, because: • the angle between the unit vector $\vec{n}$ and $\vec{B}$ is zero • **or** $\phi = B\, S \cos 0^o = B\, S\, (1)$, but B and S are positive ; therefore, ϕ is positive. Sentence 3 corresponds to the 3rd case, because: • the angle between the unit vector $\vec{n}$ and $\vec{B}$ is 180° • **or** $\phi = B\, S \cos 180^o = -B\, S$, but B and S are positive ; therefore, ϕ is negative.	**0.5** **0.5** **0.5**
2.1	During [0, 2s], the magnitude B of $\vec{B}$ changes, then the loop is crossed by a variable magnetic flux; therefore, the loop becomes the seat of induced emf. The loop forms a closed circuit, then it carries electric current.	**0.75**
2.2	During [0, 2s], B decreases, then the direction of the induced magnetic field is the same as that of $\vec{B}$ in order to oppose the decrease in B. According to the right hand rule, the induced current passes in the loop in the chosen positive sense (clockwise).	**0.75**
2.3	$\phi = \vec{B} \cdot \vec{n}\, S = B\, S \cos(\vec{B}, \vec{n}) = B\, S \cos 0^o = B\, S = B\, \pi\, r^2$ $\phi = (-0.04\, t + 0.8) \times \pi \times (0.1)^2$ $\phi = -4\pi \times 10^{-4}\, t + 8\pi \times 10^{-4}$ (SI)	**1**
2.4	$e = -\frac{d\varphi}{dt} = -(-4\pi \times 10^{-4})$, then $e = 4\pi \times 10^{-4}$ V	**1**
2.5	$i = \frac{e}{R} = \frac{4\pi \times 10^{-4}}{2} = 6.3 \times 10^{-3}$A i > 0, then the current is in the chosen positive sense (Clockwise).	**1**
2.6	The direction is the same in the two parts.	**0.5**

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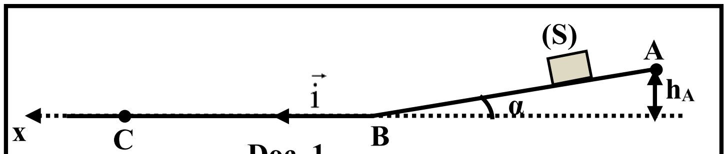
This exam is formed of three obligatory exercises in three pages.
The use of non-programmable calculator is recommended.

Exercise 1 (6.5 pts)

Determination of the force of friction

A block (S), considered as a particle, of mass m = 100 g, can slide on path ABC situated in a vertical plane. This path is formed of two parts:

- AB is straight and inclined by an angle α with respect to the horizontal ($\sin \alpha = 0.1$);
- BC is straight and horizontal.



Doc. 1

At instant $t_0 = 0$, the block (S) is released without initial velocity from point A, situated at a height h_A above the horizontal x-axis, confounded with BC, and of unit vector $\vec{i}$ (Doc. 1).

Along part AB, the motion of (S) takes place without friction, and along part BC, (S) is subjected to a force of friction $\vec{f}$ supposed constant and parallel to the displacement.

The aim of this exercise is to determine the magnitude f of the force of friction $\vec{f}$.

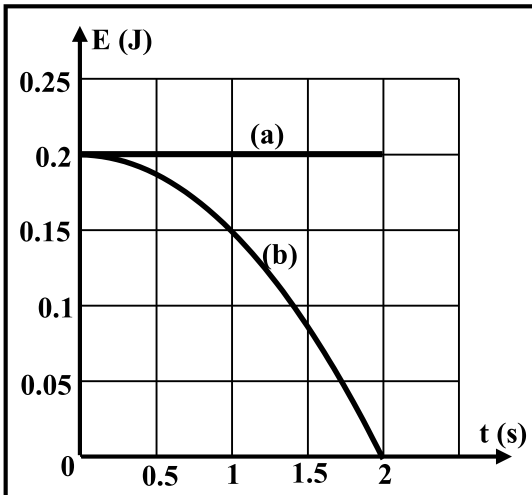
Take:

- the horizontal plane containing the x-axis as the reference level for gravitational potential energy;
- $g = 10\ m/s^2$.

1) Motion of (S) between A and B

The block (S) slides without friction along part AB and reaches B at t = 2 s.

The two curves (a) and (b) shown in document 2 represent the gravitational potential energy and the mechanical energy of the system [(S), Earth] as functions of time, during the motion of (S) between A and B.



Doc. 2

1.1) Indicate for each curve the appropriate energy. Justify.

1.2) Using document 2:

1.2.1) determine the distance AB covered by (S) along the inclined plane;

1.2.2) show that the speed of (S) at B is $V_B = 2$ m/s.

2) Motion of (S) between B and C

At t = 2 s, the block (S) reaches B and continues its motion along part BC and stops at C at t = 4 s.

2.1) Determine the linear momenta of (S), « $\vec{P}_B$ » at B and « $\vec{P}_C$ » at C.

2.2) Deduce the variation $\Delta \vec{P}$ of the linear momentum of (S) between B and C.

2.3) Show that the sum of the external forces exerted on (S) between B and C is $\Sigma \vec{F}_{ext} = -f\ \vec{i}$.

2.4) Determine the magnitude f of $\vec{f}$, knowing that $\Delta \vec{P} \cong \Sigma \vec{F}_{ext} \,.\, \Delta t$, where Δt is the duration of the motion between B and C.

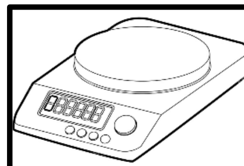
Exercise 2 (7.5 pts)

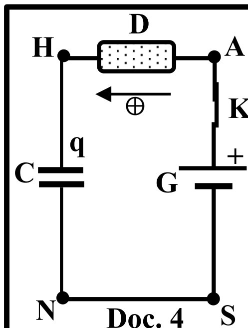
Capacitor in a digital balance

The aim of this exercise is to study the role of a capacitor in a digital balance (Doc. 3).

For this purpose, we set up the series circuit of document 4 that includes:

- an ideal battery (G) of electromotive force E;
- a resistor (D) of resistance R;
- a capacitor, initially uncharged, of capacitance C;
- a switch K.


Doc. 3



Doc. 4

1) Theoretical study

At instant $t_0 = 0$, K is closed and the charging process of the capacitor starts.
At instant t, plate H of the capacitor carries a charge q and the circuit carries a current i.

1.1) Redraw the circuit of document 4 showing on it the direction of the current i.

1.2) Show that the differential equation that governs the variation of the voltage $u_{HN} = u_C$ across the capacitor is : $E = RC\frac{du_C}{dt} + u_C$.

1.3) The solution of the obtained differential equation has the form:

$u_C = a + b\,e^{\frac{-t}{\tau}}$, where a, b and τ are constants.

Determine a, b and τ in terms of E, R and C.

1.4) Calculate the ratio $\frac{u_C}{E}$ at $t = \tau$.

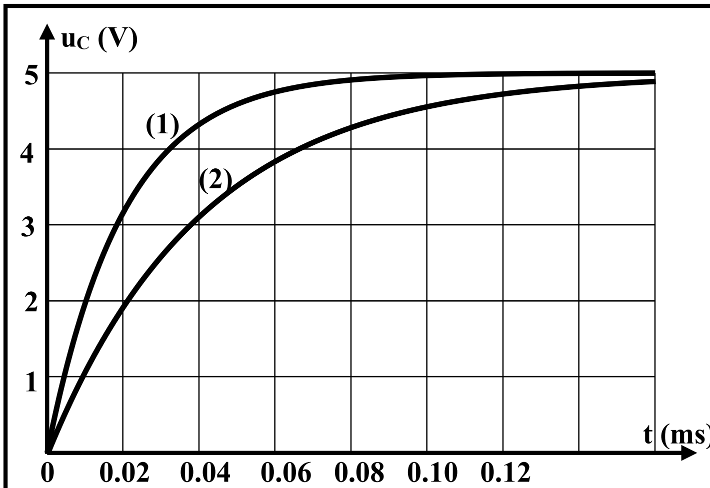
2) Measurement of the mass of an object

Document 4 is a simplified circuit used in a digital balance, where the capacitance C varies with the mass of the object placed on the balance.

Two objects of respective masses m_1 and m_2 are placed successively on this digital balance.

For each object, the capacitor in the balance has a different value of capacitance.

Curves (1) and (2) shown in document 5, represent the voltage u_C as functions of time, corresponding to each of the masses m_1 and m_2 respectively. Given that $R = 10^7\,\Omega$.



Doc. 5

2.1) Using curve (1) of document 5:

2.1.1) indicate the value of E;

2.1.2) determine the capacitance C_1 corresponding to the object of mass m_1;

2.2) Calculate m_1, knowing that the relation between the mass m of the object and the capacitance C of the capacitor is: $C = \frac{1.066\times10^{-12}}{1-m}$; (m in kg, C in F) and $0 < m < 1$ kg.

2.3) Determine whether m_1 is greater or less than m_2.

Exercise 3 (6 pts)

Diffraction of light

The aim of this exercise is to determine the width of a thin slit using the phenomenon of diffraction.

Wave Behaviors

"The visible light spectrum is the segment of the electromagnetic spectrum that the human eye can view. The human eye can detect wavelengths, in air, from 380 to 700 nanometers…

Waves across the electromagnetic spectrum behave in similar ways. When light waves encounter an object, they are either transmitted, reflected, absorbed, refracted, diffracted, or scattered depending on the composition of the object and the wavelength of the light wave.

Diffraction is the bending and spreading of waves around an obstacle. It is most clear one when a light wave strikes an object with a size comparable to its own wavelength..."

www.science.nasa.gov

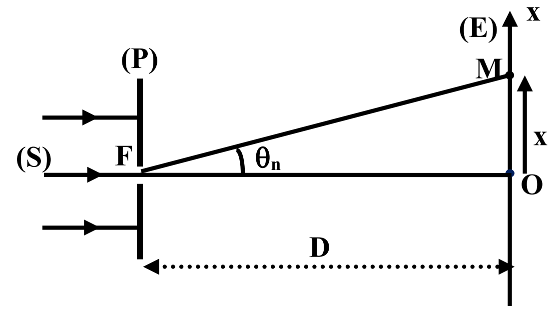
Doc. 6

1) The text of document 6 mentions that visible light waves can undergo diffraction like any electromagnetic wave. Pick out from document 6:

1.1) the statement that describes the phenomenon of diffraction of waves;

1.2) the condition to obtain a clear diffraction pattern.

2) A source (S) emits in air an electromagnetic wave of frequency $\nu = 4.34\times10^{14}$ Hz. A cylindrical beam from this source falls under normal incidence on a horizontal narrow slit F of width « a », which is cut in an opaque screen (P). A screen (E) is placed parallel to (P) at a distance D = 2 m away from it (Doc. 7).



Doc. 7

Given:

- speed of electromagnetic waves in air is $c = 3\times10^8$ m/s;
- the diffraction angles in this exercise are small;
- the diffraction angle θ_n corresponding to a dark fringe of order n is given by:

, $\sin\theta_n = \dfrac{n\lambda}{a}$, where λ is the wavelength of the electromagnetic wave, with $n = \pm1, \pm2, \pm3\ldots$

For small angles, take $\sin\theta \approx \tan\theta \approx \theta$ in radians.

2.1) Show that the wavelength of the electromagnetic wave emitted by (S) is $\lambda = 6.91\times10^{-7}$ m.

2.2) Deduce that this wave is visible by human eye.

2.3) Compare the direction of the diffraction pattern to the direction of the slit.

2.4) A point M on the screen (E) is the center of a dark fringe of order n in the diffraction pattern. The position of M is $x = \overline{OM}$ relative to the center O of the central bright fringe.

Show that the abscissa of M is $x = \dfrac{n\lambda D}{a}$.

2.5) Calculate the width « a » of the slit, knowing that the distance between O and the center of the second dark fringe is x = 6 mm.

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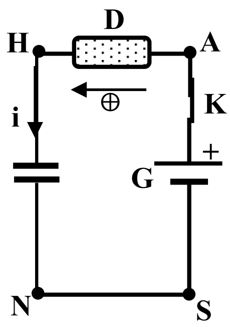
Exercise 1 (6.5 pts)	**Determination of the force of friction**	
Part	**Answer**	**Note**
1.1	Curve (a) corresponds to ME. Since no friction therefore ME = constant Curve (b) corresponds to GPE, since as height decreases GPE decreases	**0.25** **0.25** **0.25** **0.25**
1.2.1	At A: $GPE_A = 0.2$ J . But $GPE_A = mgh_A = mg(AB \sin\alpha)$ So $0.2 = 0.1\times10\times AB\times0.1$, we get: AB = 2 m	**1**
1.2.2	$ME_B = KE_B + GPE_B$ $0.2 = \frac{1}{2}\times0.1\times V_B^2 + 0$, we get $V_B = 2$ m/s	**1**
2.1	$\vec{P}_B = m\vec{V}_B$, so $\vec{P}_B = 0.2\vec{i}$; $\vec{P}_C = m\vec{V}_C = \vec{0}$ (kg m/s)	**1**
2.2	$\Delta\vec{P} = \vec{P}_C - \vec{P}_B$, so $\Delta\vec{P} = \vec{0} - 0.2\vec{i} = -0.2\vec{i}$ (kg m/s)	**1**
2.3	$\Sigma\vec{F}_{ext} = m\vec{g} + \vec{N} + \vec{f}$; $m\vec{g} + \vec{N} = \vec{0}$ So: $\Sigma\vec{F}_{ext} = \vec{f} = -f\,\vec{i}$	**1**
2.4	$\Delta\vec{P} = \Sigma\vec{F}_{ext} . \Delta t$, so $-0.2\vec{i} = -f\,\vec{i}\times 2$, we get: f = 0.1 N	**0.5**

Exercise 2 (7.5 pts)	**Capacitor in a Digital Balance**	
Part	**Answer**	**Note**
1.1		**0.25**
1.2	Law of addition of voltages: $u_{AS} = u_{AH} + u_{HN} + u_{NS}$ $E = R\,i + u_C$, but $i = \frac{dq}{dt}$ and $q = C\,u_C$ so $i = C\frac{du_C}{dt}$ This implies: $E = R\,C\frac{du_C}{dt} + u_C$	**1**
1.3	$u_C = a + b\,e^{\frac{-t}{\tau}}$ so $\frac{du_C}{dt} = -\frac{1}{\tau}\,b\,e^{\frac{-t}{\tau}}$ Replace u_C and $\frac{du_C}{dt}$ in the differential equation: $R\,C\,[-\frac{1}{\tau}\,b\,e^{\frac{-t}{\tau}}] + a + b\,e^{\frac{-t}{\tau}} = E$ then: $b\,e^{\frac{-t}{\tau}}[-\frac{RC}{\tau} + 1] + a = E$; $b\,e^{\frac{-t}{\tau}} \neq 0$ so by comparison $a = E$ and $-\frac{RC}{\tau} + 1 = 0$ so $\tau = R\,C$ $u_C = a + b\,e^{\frac{-t}{\tau}}$. But at $t = 0$; $u_C = 0$ so $b = -a = -E$ Thus, $u_C = E\,(1 - e^{\frac{-t}{\tau}})$ where $\tau = RC$	**2**
1.4	At $t = \tau$: $u_C = E\,(1 - e^{-1}) = 0.63\,E$; so $\frac{u_C}{E} = 0.63$	**0.5**
2.1.1	$E = 5$ V	**0.5**
2.1.2	At $t = \tau$: $u_C = 0.63 \times 5 = 3.15$ V Graphically $\tau = 0.02$ ms $= 2\times10^{-5}$ s $\tau = R\,C_1$ so $C_1 = 2\times10^{-12}$ F	**1**
2.2	$C_1 = \frac{1.066\times10^{-12}}{1-m_1}$ so $2\times10^{-12} = \frac{1.066\times10^{-12}}{1-m_1}$ $1 - m_1 = \frac{1.066\times10^{-12}}{2\times10^{-12}}$, we get: $m_1 = 0.467$ kg	**1**
2.3	Curve (2): $u_C = 3.15$ V at $t = \tau_2 = 0.04$ ms $= 4\times10^{-5}$ s so $C_2 = 4\times10^{-12}$ F $4\times10^{-12} = \frac{1.066\times10^{-12}}{1-m_2}$ we get $1 - m_2 = \frac{1.066\times10^{-12}}{4\times10^{-12}}$, So: $m_2 = 0.7335$ kg then $m_1 < m_2$ **Or** The curve (1) reaches its maximum value before than (2) therefore $\tau_1 < \tau_2$ then $C_1 < C_2$. But C and (1 – m) are inversely proportional, hence $1 - m_1 > 1 - m_2$ therefore $m_1 < m_2$.	**1.25**

Exercise 3 (6 pts)	Diffraction of light	
Part	**Answer**	**Mark**
1.1	Diffraction is the bending and spreading of waves around an obstacle	**1**
1.2	It is most clear one when a light wave strikes an object with a size comparable to its own wavelength.	**1**
2.1	$\lambda = \frac{c}{\upsilon}$ so $\lambda = \frac{3\times10^{8}}{4.34\times10^{14}} = 6.91\times10^{-6}$ m = 691 nm	**1**
2.2	It is visible since it is between 380 to 700 nm	**0.5**
2.3	The direction of the pattern is perpendicular to that of the slit F.	**0.5**
2.4	Dark fringe of order n : $\sin\theta_n = \frac{n\lambda}{a}$, so $\theta_n = \frac{n\lambda}{a}$ Dark fringe of order n: $\tan\theta_n = \frac{x}{D}$, so $\theta_n = \frac{x}{D}$ Thus $\frac{n\lambda}{a} = \frac{x}{D}$ this implies $x = \frac{n\lambda D}{a}$.	**1**
2.5	$x = \frac{n\lambda D}{a}$, so $6\times10^{-3} = \frac{2\times691\times10^{-9}\times2}{a}$, $a = 0.46\times10^{-3}$ m = 0.46 mm	**1**

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

Exercise 1 (7 pts)

Motion of a block on an inclined plane

A block (M), considered as a particle of mass m = 0.5 kg, can move on a straight track AF, situated in a vertical plane and inclined by an angle $\alpha = 30^o$ with the horizontal. Point A is taken as an origin of the x-axis confounded with (AF). A massless spring of natural length $\ell_0 = 50$ cm and force constant k is placed on the inclined track; one of its ends is fixed at F, and the other end is free at O (Doc. 1).

(M) is released without initial velocity from the top A of the track AF, and then it passes through point B with a velocity $\vec{V}_B$ of magnitude $V_B = \sqrt{2}$ m/s and through point C with a velocity $\vec{V}_C$ of magnitude $V_C = \sqrt{2.4}$ m/s. After point C, (M) continues its motion without friction, hits the spring, and compresses it by a distance OO'.

The aim of this exercise is to determine k.

Take:

- the horizontal plane containing (FH) as a reference level for the gravitational potential energy;
- AB = BC = 20 cm, AF = 1.6 m;
- $g = 10$ m/s^2.

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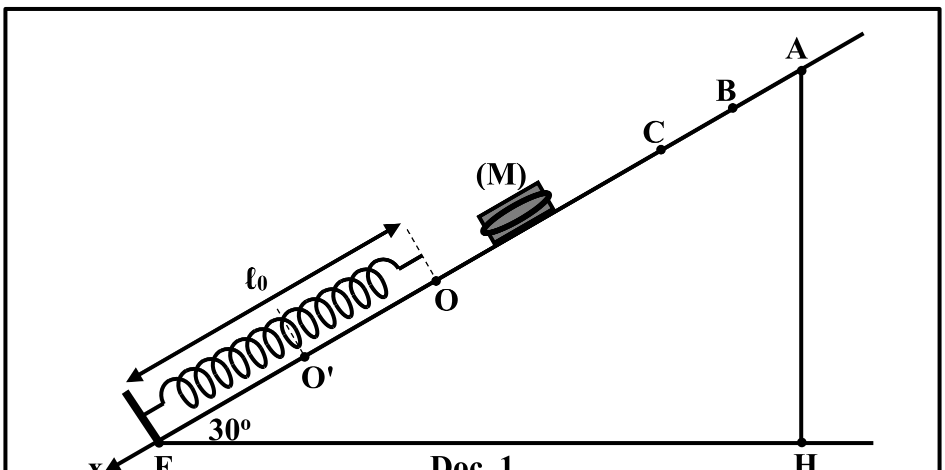


Doc. 1

1) Calculate the mechanical energy of the system [(M), Earth] at A, B and C.

2) Deduce that:

2.1) the motion of (M) between A and B takes place without friction;

2.2) (M) is submitted to a force of friction $\vec{f}$ during its motion between B and C.

3) Show that the internal energy of the system [(M), Earth, Track, Atmosphere] increases by 0.4 J during the motion of (M) between B and C.

4) Determine the magnitude f of the force of friction $\vec{f}$, supposed constant and parallel to the displacement, exerted on (M) during its motion between B and C.

5) The mechanical energy of the system [(M), Earth] at O is $ME_O = 3.6$ J. Why?

6) (M) reaches O, and compresses the spring by a maximum distance OO' = 24 cm.
Determine the value of k.

Exercise 2 (6 pts)

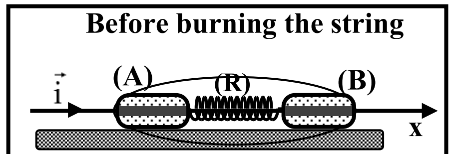
Launching of two pucks

An experimental device is made up of:

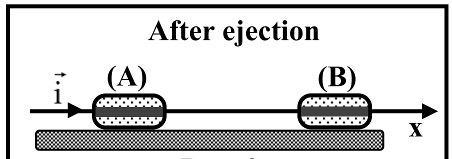
- two pucks (A) and (B), of respective masses m_A and m_B, able to move without friction on a horizontal rail;
- a spring (R) of negligible mass and of stiffness k = 100 N/m.

(R) is compressed between (A) and (B) by means of a light string to form a system at rest (Doc. 2).

We burn the string, (A) and (B) are then ejected. Just after ejection, (A) and (B) move on the horizontal rail and their centers of mass move along the horizontal x-axis of unit vector $\vec{i}$ with the velocities $\vec{v}_A$ and $\vec{v}_B$ respectively (Doc. 3).



Doc. 2



Doc. 3

The aim of this exercise is to study the effect of the mass of a puck on its speed after ejection.

Take the horizontal plane containing the x-axis as a reference level for gravitational potential energy.

1) Before burning the string, the system [(A), (B), (R)] possesses a certain form of energy « E ».

1.1) In what form is this energy stored?

1.2) Calculate the value of « E » knowing that the spring is compressed by 4 cm.

2) After ejection, the linear momentum of the system [(A), (B)] is conserved. Justify.

3) Deduce that (A) and (B) are ejected in opposite directions.

4) The used experimental device permits to measure the speed v_A of (A) after ejection. Two experiments are carried out with this device.

4.1) **Experiment 1:** The two pucks have the same mass $m_A = m_B$ = 500 g. Just after ejection, (A) moves with a velocity $\vec{v}_A = -0.4\,\vec{i}$ (v_A in m/s).

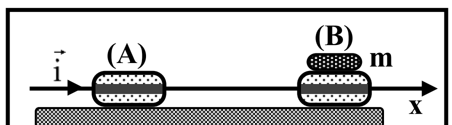
4.1.1) Determine $\vec{v}_B$.

4.1.2) Deduce the value of the kinetic energy KE of the system [(A), (B)] just after ejection.

4.1.3) Compare the obtained values of KE and « E ». Conclude.

4.2) **Experiment 2:** We repeat experiment 1 by adding an object of mass m = 100 g to puck (B), the mass of (A) remains the same (Doc. 4). Just after ejection, (A) moves with a velocity $\vec{v}_A = -0.42\,\vec{i}$ (v_A in m/s).

Determine $\vec{v}_B$.



Doc. 4

5) Deduce the effect of the increase in mass of a puck on its speed after ejection.

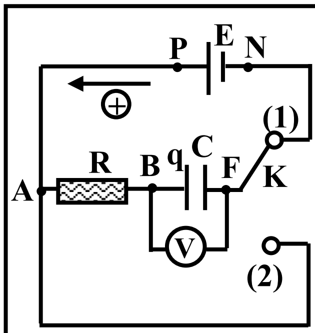
Exercise 3 (7 pts)

Time constant of RC series circuit

The aim of this exercise is to determine the time constant τ of RC series circuit during charging and discharging of a capacitor and the capacitance of a capacitor.

For this purpose, we set up the circuit of document 5 that includes:

- a capacitor, initially uncharged, of capacitance C;
- a resistor of resistance R = 100 kΩ;
- an ideal battery of constant voltage $U_{PN} = E = 12$ V;
- a voltmeter (V) connected in parallel across the terminals of the capacitor;
- a double switch K.



Doc.5

1) Charging the capacitor

At the instant $t_0 = 0$, K is placed in position (1) and the charging process of the capacitor starts.

1.1) Show that the differential equation that describes the variation of the voltage $u_{BF} = u_C$ across the capacitor is: $RC\frac{du_C}{dt} + u_C = E$.

1.2) The solution of this differential equation has the form: $u_C = E - E\,e^{\frac{-t}{\tau}}$ where τ is constant. Determine the expression of τ in terms of R and C.

1.3) At $t_1 = 7$ s, the voltage across the terminals of the capacitor equals $\frac{E}{2}$. Determine the value of τ.

1.4) Deduce the value of C.

2) Discharging the capacitor

The capacitor is completely charged.

At an instant $t_0 = 0$, taken as an initial time, the switch K is turned to position (2); the phenomenon of discharging of the capacitor thus starts.

The variation of u_C during this case is given by: $u_C = E\,e^{\frac{-t}{\tau}}$.

2.1) Show that: $\ell n\left(\frac{E}{u_C}\right) = \frac{1}{\tau}\times t$.

2.2) The table below, gives different values of $u_{BF} = u_C$ measured by the voltmeter (V) at different instants of time t .

t (s)	0	5	10	20	30	40	50
u_C (V)	12	7.3	4.4	1.6	0.6	0.2	0.08
$\ell n\left(\frac{E}{u_C}\right)$							

2.2.1) Copy and complete the table.

2.2.2) Trace, on a graph paper, the curve that represents $\ell n\left(\frac{E}{u_C}\right)$ as a function of time.

Take the scale:

- on the abscissa axis 1 cm ↔ 5 s;
- on the ordinate axis 1 cm ↔ 1.

2.2.3) Referring to the obtained curve, show that: $\ell n\left(\frac{E}{u_C}\right) = 0.1\times t$ (S.I).

2.3) Deduce the values of the time constant τ of the circuit and the capacitance C of the capacitor.

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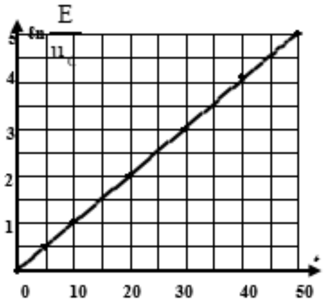
Exercise 1 (7 pts)	Motion of a block on an inclined plane	
Part	**Answer**	**Note**
1	$h_A = AF \sin30^o = 1.6 \times 0.5 = 0.8$ m $ME_A = mgh_A + 0 = 0.5 \times 10 \times 0.8 = 4$ J $ME_B = mgh_B + \frac{1}{2} m\ V_B^2 = 0.5 \times 10 \times 1.4 \times \sin30^o + \frac{1}{2} \times 0.5 \times (\sqrt{2})^2 = 4$ J $ME_C = mgh_C + \frac{1}{2} m\ V_C^2 = 0.5 \times 10 \times 1.2 \times \sin30^o + \frac{1}{2} \times 0.5 \times (\sqrt{2.4})^2 = 3.6$ J	0.5 0.5 1 0.5
2.1	Since $ME_A = ME_B = 4$ J	0.25
2.2	Since $ME_C < ME_B$; so, ME decreases thus friction exists between B and C	0.25
3	The system [(M), Earth, Track, Atmosphere] is energy isolated. So its total energy E is conserved, E = ME + U = constant So, $\Delta U = -\Delta(ME) = -(3.6 - 4) = 0.4$ J $\Delta U > 0$ so it's internal energy increases by 0.4 J.	1
4	The variation in mechanical energy equals the work of friction: $\Delta ME = W_{\vec{f}}$ so $\Delta(ME) = -0.4 = -f \times BC = -f \times 0.2$. So, f = 2 N	1
5	Since $ME_O = ME_C = 3.6$ J	0.25
6	$ME_O = ME_{O'} = KE_{O'} + PE_{g(O')} + PE_{el(O')} = 0 + mgh_{O'} + \frac{1}{2}\ kx^2$ But x = 0.24 m and v = 0, (maximum compression) $\sin30^o = \frac{h_{O'}}{FO'}$ with FO' = FO – OO' = 50 – 24 = 26 cm = 0.26 m So $h_{O'} = 0.26 \times \sin30^o = 0.13$ m, Thus, $3.6 = 0.5 \times 10 \times 0.13 + \frac{1}{2} \times k \times 0.24^2$ Hence, k = 102.43 N/m	1.75

Exercise 2 (6 pts)	Launching of two pucks	
Part	**Answer**	**Note**
1.1	In the form of elastic potential energy in the spring.	**0.5**
1.2	$E = \frac{1}{2} k x^2 = \frac{1}{2} \times 100 \times (0.04)^2 = 0.08$ J	**0.75**
2	The external forces on the system [(A), (B)] are: Weight $\vec{W}_A$ and the normal reaction $\vec{N}_A$: $\vec{W}_A + \vec{N}_A = \vec{0}$ Weight $\vec{W}_B$ and the normal reaction $\vec{N}_B$: $\vec{W}_B + \vec{N}_B = \vec{0}$ So, the sum of external forces acting on the system [(A), (B)] is nil. By Newton's second law, $\sum \overrightarrow{F_{ext}} = \frac{d\vec{P}}{dt}$, Thus, linear momentum of the system [(A), (B)] is conserved.	**0.75**
3	$\vec{P}_{before} = \vec{P}_{after}$ so $\vec{0} = m_A \vec{v}_A + m_B \vec{v}_B$ thus $\vec{v}_A = -\frac{m_B}{m_A} \vec{v}_B$ Thus, $\vec{v}_A$ has a direction opposite to $\vec{v}_B$.	**1**
4.1.1	$\vec{v}_B = -\frac{m_A}{m_B} \vec{v}_A$, so $\vec{v}_B = +0.4 \, \vec{i}$ (v_B in m/s)	**0.25**
4.1.2	$KE = \frac{1}{2} m_A v_A^2 + \frac{1}{2} m_B v_B^2 = \frac{1}{2} \times 0.5 \times 0.16 + \frac{1}{2} \times 0.5 \times 0.16 = 0.08$ J	**1**
4.1.3	KE = E = 0.08 J Conclusion : All stored elastic potential energy is converted into kinetic energy.	**0.5** **0.5**
4.2	$\vec{v}_B = -\frac{m_A}{m_B} \vec{v}_A$, so $\vec{v}_B = -\frac{0.5}{0.6} \times (-0.42 \, \vec{i}) = 0.35 \, \vec{i}$ m/s	**0.25**
5	As the mass of the puck increases, its speed decreases.	**0.5**

Exercise 3 (7 pts)	**Time constant of RC series circuit**	
Part	**Answer**	**Note**
1.1	Law of addition of voltages: $u_{PN} = u_{PA} + u_{AB} + u_{BF} + u_{FN}$ $E = R\,i + u_C$, but $i = \frac{dq}{dt}$ and $q = C\,u_C$, so $i = C\,\frac{du_C}{dt}$ Then: $E = R\,C\frac{du_C}{dt} + u_C$	**1**
1.2	$u_C = E - E\,e^{\frac{-t}{\tau}}$ so $\frac{du_C}{dt} = \frac{E}{\tau}\,e^{\frac{-t}{\tau}}$ Replace u_C and $\frac{du_C}{dt}$ in the differential equation: $R\,C\,[\frac{E}{\tau}\,e^{\frac{-t}{\tau}}] + E - E\,e^{\frac{-t}{\tau}} = E$ then: $E\,e^{\frac{-t}{\tau}}\,[\frac{RC}{\tau} - 1] + E = E$ So $E\,e^{\frac{-t}{\tau}}\,[\frac{RC}{\tau} - 1] = 0$ but $E\,e^{\frac{-t}{\tau}} \neq 0$ thus $\frac{RC}{\tau} - 1 = 0$; therefore, $\tau = R\,C$	**0.75**
1.3	$u_C = E - E\,e^{\frac{-t}{\tau}}$ so $\frac{E}{2} = E - E\,e^{\frac{-t_1}{\tau}}$, we get $E\,e^{\frac{-t_1}{\tau}} = \frac{E}{2}$ Then, $e^{\frac{-t_1}{\tau}} = \frac{1}{2}$; so $\frac{-t_1}{\tau} = -\ell n2$, then $\tau = \frac{t_1}{\ell n2} = \frac{7}{0.693} = 10.10\text{ s} \approx 10\text{ s}$	**0.75**
1.4	$\tau = R\,C$, so $10.10 = 10^5$, then $C \approx 10^{-4}$ F	**0.5**
2.1	$u_C = E\,e^{\frac{-t}{\tau}}$ so $\frac{E}{u_C} = \frac{1}{e^{\frac{-t}{\tau}}} = e^{\frac{t}{\tau}}$. Then, $\ell n\,\frac{E}{u_C} = \ell n\,e^{\frac{t}{\tau}}$. So, $\ell n\,\frac{E}{u_C} = \frac{t}{\tau}$ Hence, $\ell n\frac{E}{u_C} = \frac{1}{\tau}\times t$	**0.5**
2.2.1	$\ell n\frac{E}{u_C}$: 0 ; 0.5 ; 1 ; 2 ; 3 ; 4.1 ; 5	**1**
2.2.2		**1**
2.2.3	The graph is a straight line passing through the origin whose equation is: $\ln\frac{E}{u_C} = \text{slope}\times t$; slope = (5-0)/(50-0) = 0.1 Thus, $\ln\frac{E}{u_C} = 0.1\times t$	**0.5**
2.3	Slope = $0.1 = \frac{1}{\tau}$ which gives $\tau = 10$ s But, $\tau = RC$; thus, $C = \tau/R = 10/10^5 = 10^{-4}$ F	**0.5** **0.5**

These files have been meticulously arranged by the 'Together We Can' team, as we wish you the best of luck on your academic journey, filled with happiness and success

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