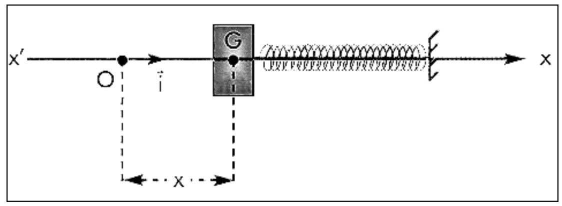
دورة سنة 2001 العادية	امتحانات شهادة الثانوية العامة فرع علوم الحياة	وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات
الاسم : الرقم :	مسابقة في الفيزياء المدة : ساعتان	

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) 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?

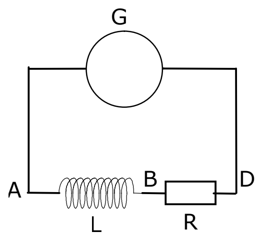
2) At the instant t = T, the speed of (S) is 2.8 ms^{-1}.

a) What is the position of G at this instant?

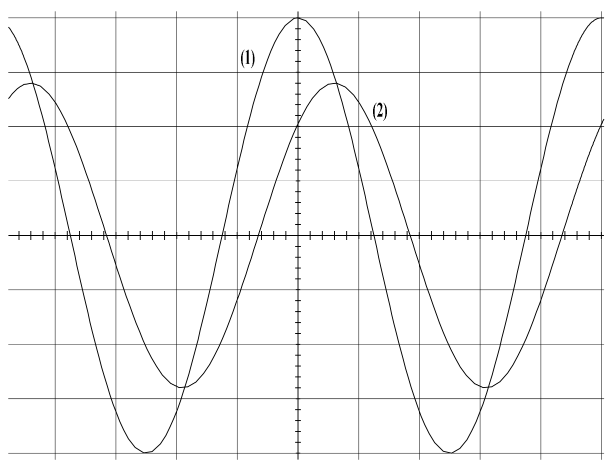
b) Calculate the work done by the forces of friction between the two instants $t_o = 0$ and t = T.

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.

<u>Third Exercise</u> (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)

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

$x'' + \frac{k}{m}x = 0$ (0.75 pt)

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)

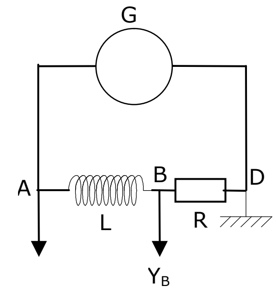
B-

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

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

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

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

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

Third Exercise (6 points)

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

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

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

2)

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

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 : ${}^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\text{e} + {}^{0}_{0}\bar{\nu}$ (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) $m_{coal} = \dfrac{4.544 \times 10^9}{30 \times 10^3} = 1.515 \times 10^5 \text{ g} = 151.5 \text{ kg}$ (0.5 pt)