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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).

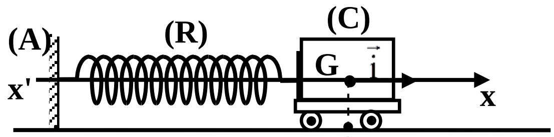

Fig.1

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).

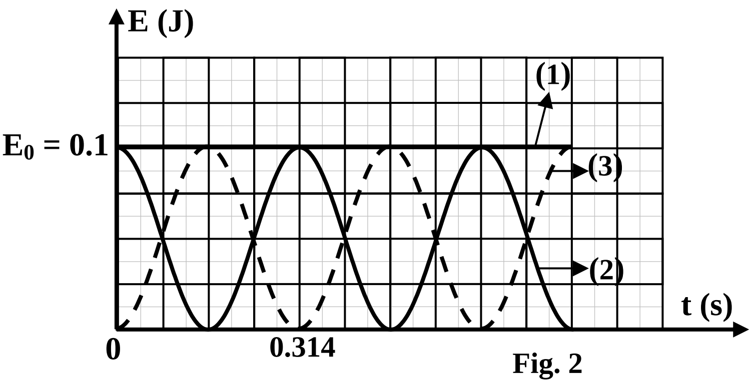

Fig. 2

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.

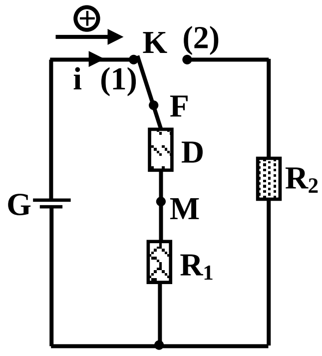

Fig.1

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.

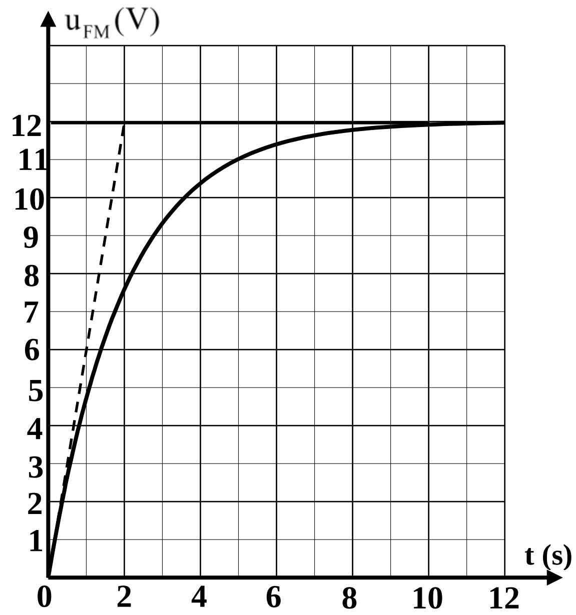

Fig. 2

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.

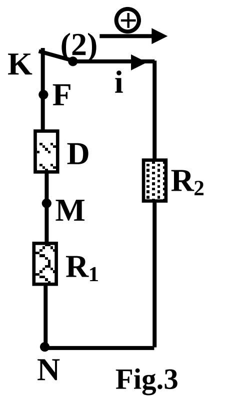

Fig.3

<u>Third exercise</u>: (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/c^2 ;
- 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 $i = \frac{dq}{dt} = C\frac{du_{LM}}{dt}$ $\Rightarrow E = u_C + R_1 C\frac{du_C}{dt} \Rightarrow \frac{du_C}{dt} + \frac{1}{R_1 C}u_C = \frac{E}{R_1 C}$	1 ½
A.5	$u_C = A + B\, e^{-\frac{t}{\tau}}$. at t = 0 $\Rightarrow 0 = A + B \Rightarrow A = -B$ $\frac{du_C}{dt} = -\frac{B}{\tau}e^{-t/\tau} \Rightarrow -\frac{B}{\tau}e^{-t/\tau} + \frac{A}{R_1 C} + \frac{B}{R_1 C}e^{-t/\tau} = \frac{E}{R_1 C}$ By identification A = E and $\tau = R_1 C$; 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	$\tau = R_1 C \Rightarrow C = \frac{2}{100} = 0.02F = 20$ 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	$u_{FM} = u_{FN} + u_{NM} \Rightarrow u_{FM} = R_2 i + R_1 i = (R_2 + R_1)\, i \Rightarrow (u_{FM})_{max} = (R_2 + R_1)\, I_{max} = 10$ 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