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: (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).

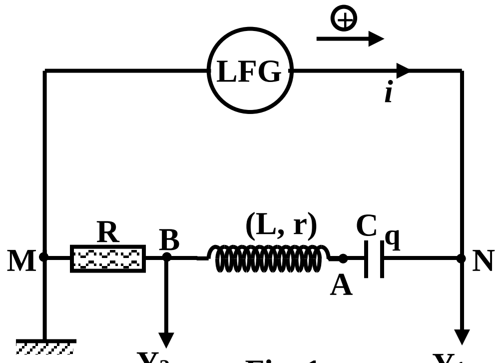

Fig. 1

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.

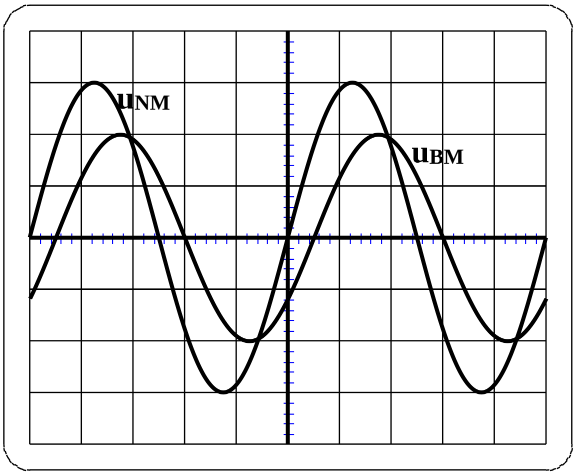

Fig. 2

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).

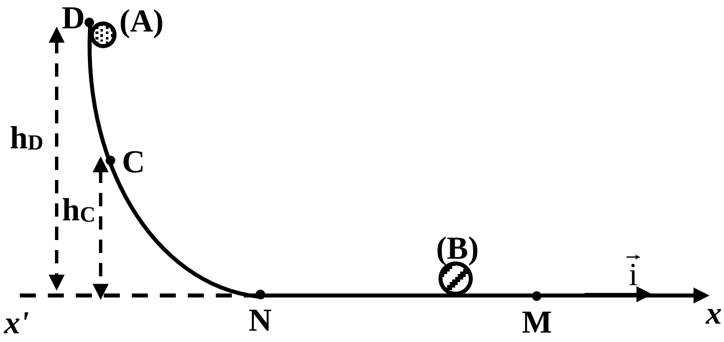

Fig. 1

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.

<u>Third exercise</u>: (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.

First exercise (7 points)

Part of the Q	Answer	Note
1.a	$T = 5\text{ div}\times 1\text{ ms/div} = 5\text{ ms} = 5\times 10^{-3}\text{s}$ $\omega = \frac{2\pi}{T} = 400\pi\text{ rad/s} = 1256\text{ rad/s}.$	**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	$\varphi = \frac{2\pi\times 0.5}{5} = 0.2\pi$ rad. u_R lags u_g by $0.2\,\pi$	**0.5**
2	$i = 0.05\cos(400\,\pi t - 0.2\pi)$	**0.5**
3.a	$P = UI\cos\varphi = \frac{3\times 0.05}{\sqrt{2}\times\sqrt{2}}\cos 0.2\pi = 0.06\text{ W}$	**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	$i = C\frac{du_C}{dt} \Rightarrow u_C = \frac{1}{C}\int i dt = \frac{0.05}{400\pi C}\sin(400\pi t - 0.2\pi) = \frac{25}{\pi}\sin(400\pi t - 0.2\pi)$	**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 ⇒ mechanical energy of the system [(A), Earth] is conserved : $ME_{(D)} = ME_{(N)}$; $0 + m_A g h_D = ½\, m_A V_{1A}^2 \Rightarrow V_{1A}^2 = 2gh_D \Rightarrow V_{1A} = 3$ m/s.	**1**
3- a	Linear momentum of the system [(A), (B)] before collision: $\vec{P}_S = m_A \vec{V}_{1A} + m_B \vec{V}_{1B} = (2\times3\,\vec{i}\,) + [4\times(-1\,\vec{i}\,)] = 2\,\vec{i}$ (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] $0 + m_A g h_C = ½\, m_A V_{2A}^2 \Rightarrow V_{2A}^2 = 2gh_C \Rightarrow V_{2A} = \sqrt{5.4} = 2.323$ 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)] $KE_{before} = ½\, m_A V_{1A}^2 + ½\, m_B V_{1B}^2 = 11$ J $KE_{after} = ½\, m_A V_{2A}^2 + ½\, m_B V_{2B}^2 = 5.4 + ½\times4\times(1.66)^2 = 5.4 + 5.58 = 10.91 \text{ J} \approx 11$ J ⇒ the collision is elastic	**1.25**

Third exercise (6 points)

Part of the Q	Answer	Note
A.1	${}^{23}_{11}Na + {}^{1}_{0}n \longrightarrow {}^{24}_{11}Na$	**0.5**
A.2	Provoked since it needs an external intervention.	**0.5**
B.1	${}^{24}_{11}Na \longrightarrow {}^{A}_{Z}X + {}^{0}_{-1}e + {}^{0}_{0}\bar{\upsilon} + \gamma$ 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. **<u>Another method</u>** : t = n. T ; T = ln2/ λ ⇒ 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**