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.

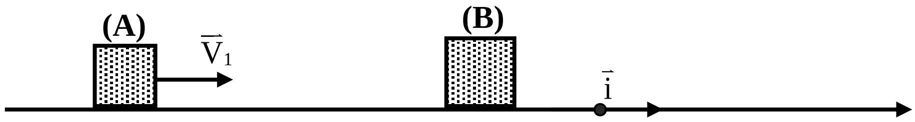
First exercise: (6 points)

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.

<u>Second exercise</u>: (7 points)

Characteristic of an electric component

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 $u = u_{AM}$.

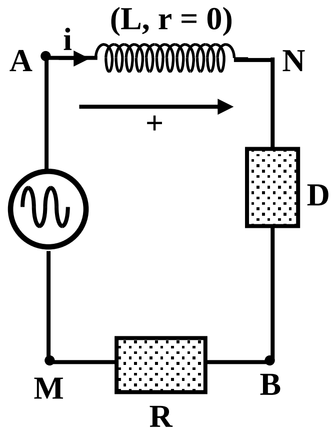


Fig.1

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.

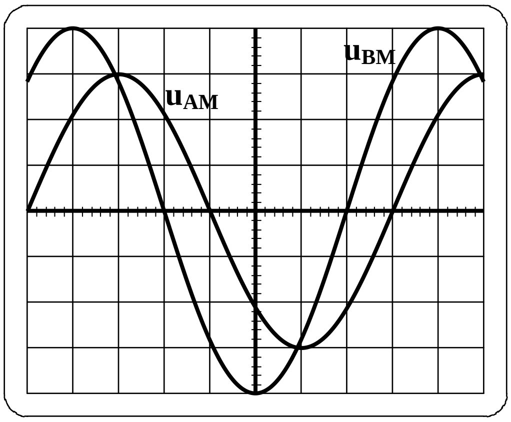


Fig.2

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:

$$u_{NB} = -\frac{0.02}{250\pi C}\cos(\omega t + \frac{\pi}{4}) \quad (u_{NB} \text{ in V ; C in F ; t in s})$$

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 $f = f_0 = \frac{1000}{\pi}$ 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.

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

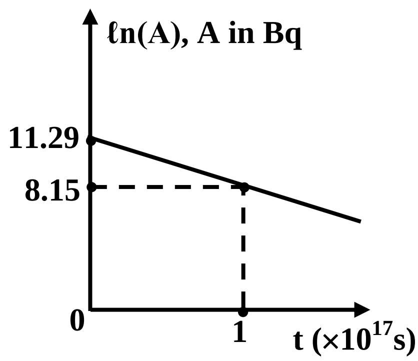
2) Uranium $^{235}_{92}U$ is an α emitter.
a) Write down the equation of disintegration of uranium $^{235}_{92}U$ and identify the nucleus produced.
Given:

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.



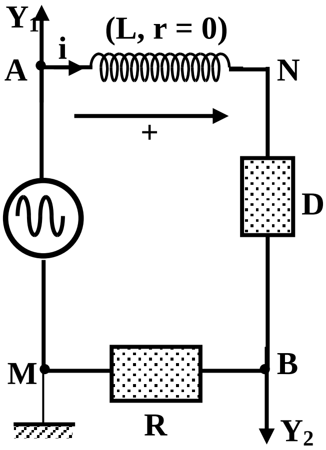
i) Show that the shape of the graph, in the adjacent figure, agrees with the expression of $\ell n(A)$.
ii) Using the adjacent figure determine, in s^{-1}, the value of the radioactive constant λ.
iii) Deduce the value of the radioactive period T of $^{235}_{92}U$.

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	$\frac{\Delta \vec{P}_A}{\Delta t} = \vec{F}_{B/A} = \frac{-0.24\vec{i}}{0.04} = -6\,\vec{i}$ (N) . $\frac{\Delta \vec{P}_B}{\Delta t} = \vec{F}_{A/B} = \frac{0.24\vec{i}}{0.04} = 6\,\vec{i}$ (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	$U_{m(R)} = 0.5\times 4 = 2$ V $\Rightarrow I_m = \frac{U_m(R)}{R} = 2\times 10^{-2}$ A	¾
A.2.d	$\lvert\varphi\rvert = \frac{2\pi}{8} = \frac{\pi}{4}$ rad ; i leads u_{AM}	¾
A.3	i leads u_{AM} $\Rightarrow$ (D) is a capcitor	+
A.4	$i = 2\times 10^{-2}\ \sin(250\pi t + \frac{\pi}{4})$ (i in A and t in s)	½
A.5	$i = C\frac{du_{NB}}{dt} \Rightarrow u_{NB} = \frac{1}{C}\int i\,dt = \frac{1}{C}\int 0.02\sin(\omega t + \frac{\pi}{4})dt$ $\Rightarrow u_{NB} = -\frac{0.02}{250\pi C}\cos(250\pi t + \frac{\pi}{4})$	¾
A.6	$U_m\sin(\omega t) = L\omega I_m\cos(\omega t + \frac{\pi}{4}) - \frac{0.02}{250\pi C}\cos(250\pi t + \frac{\pi}{4}) + 2\sin(\omega t + \frac{\pi}{4})$ $t = 0 \Rightarrow 0 = L\omega I_m\frac{\sqrt{2}}{2} - \frac{0.02}{250\pi C}\times\frac{\sqrt{2}}{2} + 2\frac{\sqrt{2}}{2} \Rightarrow C = 1.06\times 10^{-6}$ F	**1.25**
B.1	Current resonance	+
B.2	$f_0 = \frac{1}{2\pi\sqrt{LC}} \Rightarrow C = 1.06\times 10^{-6}$ 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 = 4.739×10^{-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 = 2.379×10^{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 ⇒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 ⇒ compatible with the graph.	½
B.2.d.ii	λ = – 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