	مسابقة في مادة الفيزياء	الاسم:
	المدة: ساعتان	الرقم:

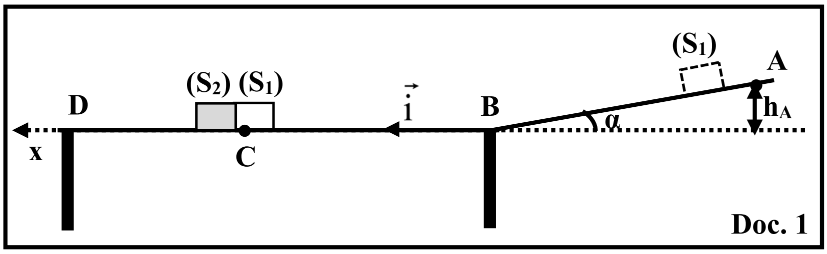
This exam is formed of three obligatory exercises in three pages.
The use of non-programmable calculator is recommended.

Exercise 1 (7 pts) Motion of two blocks

The aim of this exercise is to determine the distance traveled by two blocks (S_1) and (S_2) after their collision.
Consider:

- Two blocks (S_1) and (S_2), considered as particles, of masses $m_1 = 100$ g and $m_2 = 150$ g respectively;
- a straight rail AB inclined at an angle α with respect to the horizontal ($\sin\alpha = 0.1$);
- a horizontal table BCD.

The x-axis is horizontal, passing through B, C and D, and is oriented along the unit vector $\vec{i}$ (Doc. 1).



Take:

- the horizontal plane containing (BD) as the reference level for gravitational potential energy;
- $g = 10\ m/s^2$.

1) Motion of (S_1) between A and B

At $t_0 = 0$, block (S_1) at point A, is located at an altitude h_A above the horizontal plane containing (BD). Then it descends along rail AB and reaches point B at t = 2 s.
E_1 and E_2 are the expressions, as functions of time, of the kinetic energy KE of (S_1) and the gravitational potential energy GPE of the system [(S_1) - Earth] between $t_0 = 0$ and t = 2 s.

$$E_1 = 0.05\ t^2 + 0.05\ t + 0.0125\ (S.I) \quad ; \quad E_2 = -0.05\ t^2 - 0.05\ t + 0.3\ (S.I)$$

1.1) Calculate, at an instant t, the mechanical energy of the system [(S_1) - Earth] between A and B.
1.2) Deduce that the force of friction is negligible between A and B.
1.3) E_1 corresponds to KE and E_2 corresponds to GPE. Justify.
1.4) Deduce:
1.4.1) that the speed of (S_1) is not zero at point A.
1.4.2) the value of the altitude h_A.
1.5) Determine the speed of (S_1) at B.

2) Collision between (S_1) and (S_2)

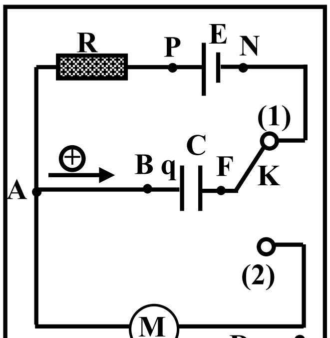
Block (S_1) reaches point B and continues its motion along BC with a velocity $\vec{V} = 2.5\ \vec{i}$ (m/s).
It collides head-on with block (S_2), initially at rest at C. Just after the collision, (S_1) and (S_2) form a single body (S) and moves with a velocity $\vec{V'} = V'\ \vec{i}$.
After the collision, (S) is subjected to a frictional force $\vec{f} = -0.5\ \vec{i}$ (N) and stops after traveling a distance d.

2.1) Determine by applying the principle of conservation of linear momentum for the system [(S_1), (S_2)], the velocity $\vec{V'}$ of (S) just after the collision.
2.2) Calculate, after the collision, the variation in the mechanical energy of the system [(S), Earth] between C and the point where (S) stops.
2.3) Deduce that (S) will stop before reaching the end D of the table, given that CD = 0.5 m.

Exercise 2 (6.5 pts) Energy conversion through a capacitor

The aim of this exercise is to study the conversion of electrical energy into mechanical energy during discharging a capacitor through the motor of a toy car.
For this purpose, we set up the circuit of document 2 that includes:

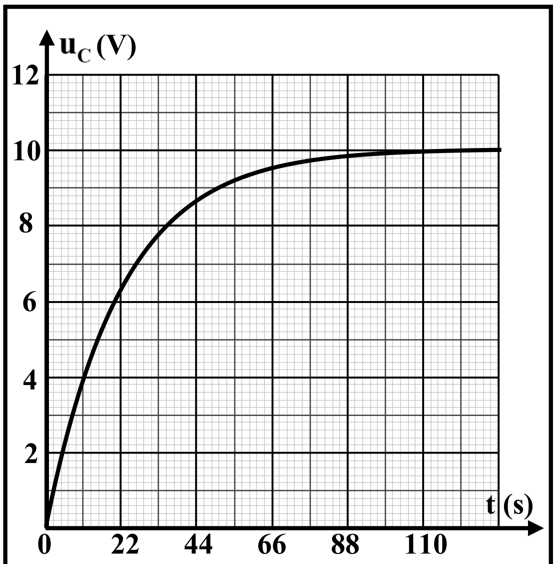
- a capacitor, initially uncharged, of capacitance C;
- a resistor of resistance R = 10 kΩ;
- an ideal battery of constant voltage $U_{PN} = E$;
- a motor (M) of a toy car;
- a double switch K.



Doc. 2

1) Charging the capacitor

At the instant $t_0 = 0$, K is placed in 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.



Doc. 3

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 is:
$u_C = E(1 - e^{\frac{-t}{\tau}})$ where $\tau = RC$ is the time constant of the circuit. Document 3 shows u_C as a function of time.

1.2.1) Referring to document 3, indicate the value of E.
1.2.2) Using document 3, determine the value of τ.
1.2.3) Deduce that C = 2200 μF.
1.2.4) Deduce, in terms of t, the expression of the current i.

1.3) Choose with justification the correct answer.
The capacitor is completely charged.

1.3.1) The time taken by the capacitor to become practically completely charged is:
a) 0.63 τ b) τ c) 5 τ d) $\frac{\tau}{2}$

1.3.2) The value of the charge q of plate B is:
a) 0 b) 0.0022 C c) 0.022 C d) 0.1 C

1.3.3) The current i is:
a) 0 b) 2.2 mA c) 10 mA d) 100 mA

1.3.4) The electric energy stored in the capacitor is:
a) 0 b) 0.0011 J c) 0.11 J d) 1.1 J

2) Discharging the capacitor

The capacitor is completely charged. At instant $t_0 = 0$, taken as a new initial time. The switch K is turned to position (2); the phenomenon of discharging the capacitor thus starts and the motor turns, causing a small toy car to move. When the voltage across the capacitor becomes $u_{BF} = u_C = 2$ V the motor stops.

2.1) Indicate the value of the electric energy W_0 stored in the capacitor at $t_0 = 0$.
2.2) Calculate the electric energy W_1 that remains in the capacitor when the motor stops.
2.3) Deduce the value of the electric energy W_e consumed by the motor during its functioning.
2.4) Calculate the useful energy W_u furnished by the motor during its functioning, knowing that its efficiency is $r = \frac{W_u}{W_e} = 20\ \%$.

Exercise 3 (6.5 pts) **Stability of nuclei**

The aim of this exercise is to study the stability of certain nuclei and the disintegration of unstable nuclei.

1) Uranium-238 nucleus

Consider the uranium-238 nucleus ($^{238}_{92}U$) of mass $m_U = 237.99905$ u.

Given: $1\ u = 931.5\ \frac{MeV}{c^2}$; mass of proton: $m_p = 1.00727$ u; mass of neutron: $m_n = 1.00866$ u.

1.1) Indicate the constituents of uranium-238 nucleus.

1.2) Show that the mass defect of uranium-238 nucleus is $\Delta m = 1.93415$ u.

1.3) This mass defect is converted into energy equivalent to the binding energy E_B of the nucleus.

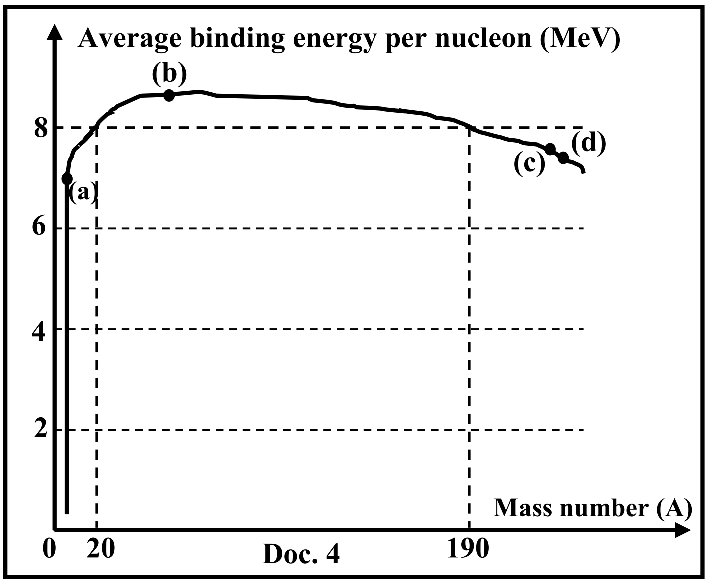
1.3.1) Define the binding energy of a nucleus.

1.3.2) Calculate the binding energy per nucleon of uranium-238.

2) Stability of a nucleus

Consider the nuclei: uranium-238 nucleus ($^{238}_{92}U$), thorium-234 ($^{234}_{90}Th$), iron-56 ($^{56}_{26}Fe$) and helium-4 ($^{4}_{2}He$).

Aston's curve in document 4 represents the average binding energy per nucleon $\left(\frac{E_B}{A}\right)$ as a function of mass number A.



2.1) Match each of the following nuclei: $^{238}_{92}U$, $^{234}_{90}Th$, $^{56}_{26}Fe$ and $^{4}_{2}He$ to one of the nuclei (a), (b), (c) and (d) on Aston's curve.

2.2) Deduce the most stable nucleus.

2.3) The binding energy of each of the nuclei $^{234}_{90}Th$, $^{56}_{26}Fe$ and $^{4}_{2}He$, is given in the table below.

Nucleus	$^{4}_{2}He$	$^{56}_{26}Fe$	$^{234}_{90}Th$
Binding energy E_B (MeV)	28.28	492.24	1778.4

Calculate the binding energy per nucleon for each nucleus.

2.4) Show that the obtained results are in agreement with part **2.2**.

2.5) Choose the correct answer.

The interaction between the nucleons which assures the stability of the nucleus is called:

a) electrostatic interaction.

b) strong interaction.

c) gravitational interaction.

3) Disintegration of unstable nucleus

Uranium-238 is radioactive. It disintegrates into thorium-234 according to the following equation:

$$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{A}_{Z}X$$

3.1) Calculate Z and A indicating the used laws.

3.2) Name the emitted particle $^{A}_{Z}X$.

3.3) Choose the correct answer.

A parent nucleus disintegrates into a daughter nucleus, the binding energy per nucleon of the daughter nucleus is:

a) equal to that of the parent nucleus.

b) less than that of the parent nucleus.

c) greater than that of the parent nucleus.

مسابقة في مادة الفيزياء
أسس التصحيح - إنكليزي

Exercise 1 (7 pts)	Motion of Two Blocks	
Part	**Answer**	**grade**
1.1	ME = $E_1 + E_2 = 0.05\ t^2 + 0.05\ t + 0.0125 - 0.05t^2 - 0.05\ t + 0.3 = 0.3125$ J	**0.5**
1.2	**ME = constant**, so friction force is negligible between A and B	**0.25**
1.3	E_1 corresponds to kinetic energy Because as time increases, this energy increases, which indicates that the speed increases—typical behavior during the downward motion of a body without friction on an inclined plane. E_2 corresponds to gravitational potential energy, Because it decreases with time, which is consistent with a block descending along the rail AB. As its altitude relative to the reference level decreases, the gravitational potential energy (GPE = mgh) decreases (with m and g constants).	**0.5** **0.5**
1.4.1	$KE = 0.05t^2 + 0.05\ t + 0.0125$ At point A : $t_0 = 0$, KE = 0.0125 J ≠ 0 then $V_A \neq 0$.	**0.5**
1.4.2	GPE = $m_1.g.h_A = 0.3$, then $h_A = 0.3$ m	**1**
1.5	$KE = 0.05\ t^2 + 0.05\ t + 0.0125$ at t = 2 s : KE = 0.3125 J $\frac{1}{2} m V_B^2 = 0.3125$,then $V_B^2 = 6.25$; therefore, $V_B = 2.5$ m/s	**0.75**
2.1	System [(S_1), (S_2)]: during the collision, $\vec{P}_{before} = \vec{P}_{after}$ $m_1 \vec{V} + m_2 \vec{0} = (m_1 + m_2) \vec{V'}$ Then, $0.1 \times 2.5\ \vec{i} = (0.1 + 0.15) \vec{V'}$,therefore $\vec{V'} = 1\ \vec{i}$ (m/s)	**1**
2.2	$\Delta ME = ME_f - ME_C = KE_f + GPE_f - (KE_c + GPE_c) = 0 - [\frac{1}{2}(m_1 + m_2) V'^2 + 0]$ $\Delta ME = -0.5 \times 0.25 \times 1^2 = -0.125$ J	**1**
2.3	The variation in the mechanical energy is equal to the work done by the friction force: $\Delta ME = W_{\vec{f}}$, then $\Delta(ME) = -0.125 = -f \times d$ $-0.125 = -0.5 \times d$, then d = 0.25 m Since d < CD, the block stops before reaching point D.	**1**

Exercise 2 (6.5 pts)	Energy conversion through a capacitor	
Part	**Answer**	**grade**
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 $q = C\,u_C$ Then $i = C\,\frac{du_C}{dt}$; therefore : $E = R\,C\frac{du_C}{dt} + u_C$	**1**
1.2.1	$E = 10$ V	**0.25**
1.2.2	At $t = \tau$: $u_C = E\,(1 - e^{-1}) = 0.63\,E = 6.3$ V which graphically corresponds to $\tau = 22$ s	**0.75**
1.2.3	$\tau = 22$ s and $\tau = R \times C$; $C = \frac{\tau}{R} = \frac{22}{10000} = 2.2 \times 10^{-3}$ F $= 2200\ \mu$F	**0.5**
1.2.4	$i = C\,\frac{du_C}{dt}$; $i = \frac{C}{\tau}\,E\,e^{-\frac{t}{\tau}} = \frac{E}{R}\,e^{-\frac{t}{\tau}}$; $i = 1\times10^{-3}\,e^{-\,t/22}$ (i in A and t in s)	**0.75**
1.3.1	**c) $t = 5\tau$** because $u_c = E\,(1 - e^{-5}) = 99\,\%\,E$ so the capacitor is practically fully charged.	**0.5**
1.3.2	**c) q = 0.022 C** Because when the capacitor is fully charged, we get: $q = Q = EC = 10 \times 2.2 \times 10^{-3} = 0.022$ C	**0.5**
1.3.3	**a) i = 0** because when the capacitor is almost fully charged we have $t = 5\tau$ and since $i = 1\times10^{-3}\,e^{-\,t/22} \approx 0$ A	**0.5**
1.3.4	**c) W = 0.11 J** because $W = \frac{1}{2}C\,u_C^2 = \frac{1}{2}C\,E^2 = \frac{1}{2} \times 2.2 \times 10^{-3} \times 10^2 = 0.11$ J	**0.5**
2.1	At $t_0 = 0$, $W_0 = 0.11$ J	**0.25**
2.2	$W_1 = \frac{1}{2}C\,u_C^2 = \frac{1}{2} \times 2.2 \times 10^{-3} \times 2^2 = 0.0044$ J	**0.5**
2.3	$W_e = 0.11 - 0.0044 = 0.1056$ J	**0.25**
2.4	$W_u = 0.2 \times 0.1056 = 0.02112$ J	**0.25**

Exercise 3 (6.5 pts)	Stability of nuclei	
Part	**Answer**	**Note**
1.1	The uranium $^{238}_{92}U$ is composed of: **Protons**: Z = 92 **Neutrons**: N = A – Z = 238 – 92 = 146	**0.25** **0.25**
1.2	Mass of nucleons taken separately = $Z\times m_p + N\times m_n = 92\times m_p + 146\times m_n$ $= 92\times1.00727 + 146\times1.00866$ $= 239.9332$ u Δm = Mass of nucleons taken separately – mass of nucleus = 239.9332 – 237.99905 Δm = 1.93415 u	**0.75**
1.3.1	Binding energy is the minimum energy that must be given to the nucleus to separate all its nucleons.	**0.5**
1.3.2	$E_B = \Delta m \times c^2 = 1.93415 \times 931.5\ \frac{MeV}{c^2} \times c^2 = 1801.66$ MeV ; $\frac{E_B}{A} = 7.57$ MeV	**1**
2.1	$^{238}_{92}U \rightarrow$ (d) $^{234}_{90}Th \rightarrow$ (c) $^{56}_{26}Fe \rightarrow$ (b) $^{4}_{2}He \rightarrow$ (a)	**1**
2.2	The most stable nucleus is iron , since it has the greatest $\frac{E_B}{A}$.	**0.25**
2.3	Nucleus / Binding energy E_B (MeV) / $\frac{E_B}{A}$ (MeV): $^{4}_{2}He$ / 28.28 / 7.07 $^{56}_{26}Fe$ / 492.24 / 8.79 $^{234}_{90}Th$ / 1778.4 / 7.6	**0.75**
2.4	$\left.\frac{E_B}{A}\right)_{Fe}$ the largest value	**0.25**
2.5	**b)** → Strong interaction	**0.25**
3.1	Conservation of mass number: 238 = 234 + A , therefore A = 4 Conservation of charge number: 92 = 90 + Z , therefore Z = 2	**0.75**
3.2	Helium nucleus	**0.25**
3.3	**c)** greater than that of the parent nucleus	**0.25**