مسابقة في الثقافة العلمية: مادة الفيزياء	الاسم:
المدة: ساعة واحدة	الرقم:

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

Exercise 1 (7 ½ pts)

Bouncing of a ball

Consider a ball taken as a particle (S) of mass m = 100 g. (S) is suspended from the lower end of an inextensible massless string, of length 1 m, whose upper end is attached to a fixed point O.

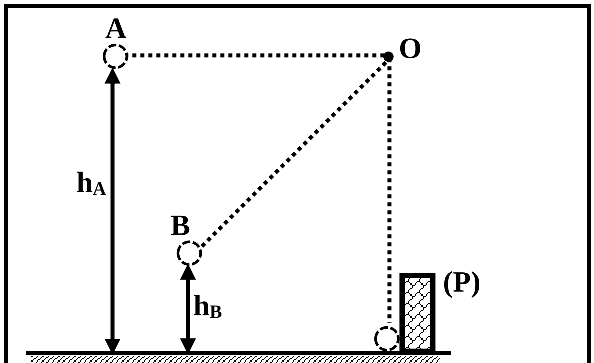
The system [(S) - String] is shifted from its equilibrium position by an angle of 90^0, and then (S) is released from rest from point A of height h_A = 1 m above the ground. (S) reaches the ground at point C (Doc. 1).

Air resistance is neglected during the motion of (S).

The aim of this exercise is to study whether (S) is suitable for a certain sports game.

Take:

- the horizontal plane containing C as a reference level for the gravitational potential energy of the system [(S) - Earth];
- $g = 10\ m/s^2$.



Doc.1

1) Calculate the kinetic energy KE_A of (S) at A.
2) Calculate the gravitational potential energy GPE_A of the system [(S) - String - Earth] at A.
3) Show that the mechanical energy ME_A of the system [(S) - String - Earth] at A is ME_A = 1 J.
4) The mechanical energy of the system [(S) - String - Earth] is conserved during the motion of (S) from A to C. Why?
5) As (S) reaches the ground at point C, it collides with a plate (P) fixed at the ground. During this collision the system [(S) - String - Earth] loses 55 % of its mechanical energy, and then (S) bounces back and attains a new maximum height h_B.
   - 5.1) Calculate the mechanical energy of the system [(S) - String - Earth] after the collision with the plate (P).
   - 5.2) Deduce that h_B = 0.45 m.
6) Calculate the ratio $\frac{h_B}{h_A}$.
7) The ball (S) is suitable to be used in a certain sports game if the bouncing ratio is $r = \frac{h_B}{h_A} = 0.54$.

   Deduce whether (S) is suitable for this game.

Exercise 2 (6 ½ pts)

The age of the lunar rocks

The aim of this exercise is to determine the age of the lunar rocks brought back by the Apollo XI astronauts. A sample (A) of this rock is collected. This sample contains certain quantities of the radioactive isotope, potassium-40 (${}^{40}_{19}K$), as well as the product obtained by its disintegration, argon-40 (${}^{40}_{18}Ar$).

1) Define radioactivity.

2) Indicate the composition (number of protons and number of neutrons) of potassium-40.

3) One of the decay equations of potassium-40 is: ${}^{40}_{19}K \rightarrow {}^{40}_{18}Ar + {}^{A}_{Z}X$.
Calculate Z and A indicating the used laws.

4) Indicate the name and the symbol of the emitted particle.

5) The half-life (period) of potassium-40 is: $T = 1.25 \times 10^9$ years.

5.1) Define the half-life of a radioactive substance.

5.2) Given that $m_1 = \frac{1}{8} m_0$, where m_1 is the mass of potassium-40 found in the sample (A) and m_0 is the initial mass of potassium-40 present in the sample (A) when it is formed at $t_0 = 0$.
Determine the age of this sample.

Exercise 3 (6 pts)

Electric energy produced in a nuclear power plant

A nuclear power plant generates electricity from the nuclear energy produced inside its nuclear reactors. Suppose that the nuclear reaction that takes place inside a reactor is:

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,{}^{1}_{0}n$$

Given:

Particle or Nucleus	${}^{1}_{0}n$	${}^{235}_{92}U$	${}^{144}_{56}Ba$	${}^{89}_{36}Kr$
Mass in u	1.008	234.994	143.922	88.917

Speed of light in vacuum $c = 3\times10^8$ m/s ; $1u = 1.66\times10^{-27}$ kg ; $1MeV = 1.6\times10^{-13}$ J.

1) The above nuclear reaction is fission. Justify.

2) Show that the loss of mass in this reaction is $\Delta m = 0.139$ u.

3) Determine, in joules, the energy E liberated by this reaction.

4) Show that the value of this energy in MeV is $E \cong 129.8$ MeV.

5) Knowing that 34% of the nuclear energy E is transformed into electrical energy E', calculate E' in MeV.

Exercise 1 (7 ½ pts) Bouncing of a ball

Part		Answer	Mark
1		$KE_A = \frac{1}{2}mv^2 = 0$ m/s	1
2		$GPE_A = mgh_A = 0.1 \times 10 \times 1 = 1$ J	1
3		$ME_A = KE_A + GPE_A = 0 + 1 = 1$ J	1
4		The air resistance is neglected.	0.5
5	5.1	The remaining mechanical energy just after the collision is: $ME' = 0.45 \times 1 = 0.45$ J	1
	5.2	$ME' = KE' + GPE'$ $0.45 = 0 + mgh_{A'}$, $h_{A'} = 0.45$ m	1
6		$r = \frac{h_{A'}}{h_A} = r = \frac{0.45}{1} = 0.45$	1
7		No, since $r \neq 0.54$	1

Exercise 2 (6 ½ pts) The age of the lunar rocks

Part		Answer	Mark
1		The radioactivity is a spontaneous transformation of a nucleus into another one, with emission of radioactive radiation.	1
2		Number of protons Z = 19, number of neutrons N = 21	0.5
3		According to the law of conservation of mass number : 40 = 40 + A ; A = 0 According to the law of conservation of atomic number: 19 = 18 + Z ; Z = 1 $^{40}_{19}K \rightarrow ^{40}_{18}Ar + ^{0}_{+1}X$	0.5 0.5
4		Name : Positron Symbol : $^{0}_{+1}e$	0.5 0.5
5	5.1	The half-life of a radioactive substance is the time after which half of the radioactive substance is disintegrated.	1
	5.2	$\frac{m_i}{m_f} = 2^n, \frac{m_i}{\frac{1}{8}m_i} = 2^n, 2^3 = 2^n, n = 3$ Therefore : $t = nT = 3 \times 1.25 \times 10^9$ years $= 3.84 \times 10^9$ years	2

Exercise 3 (6 pts) Electric energy produced in a nuclear power plant

Part	Answer	Mark
1	This is a provoked nuclear reaction in which a heavy nucleus is divided into two lighter nuclei under the impact of a neutron.	1
2	$\Delta m = m_{before} - m_{after} = (234.994 + 1.008) - (143.922 + 88.917 + 3\times1.008)$ Then : $\Delta m = 0.139$ u	1
3	$E = \Delta m \times c^2$ $\Delta m = 0.139 \times 1.66\times10^{-27} = 0.2307\times10^{-27}$ kg $E = 0.2307\times10^{-27} \times (3\times10^8)^2 = 2.0766\times10^{-11}$ J	2
4	$E = 2.0766\times10^{-11} / 1.6\times10^{-13} = 129.79$ MeV ≈ 129.8 MeV	1
5	$E' = 0.34 \times 129.8$ MeV $= 44.132$ MeV	1