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

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

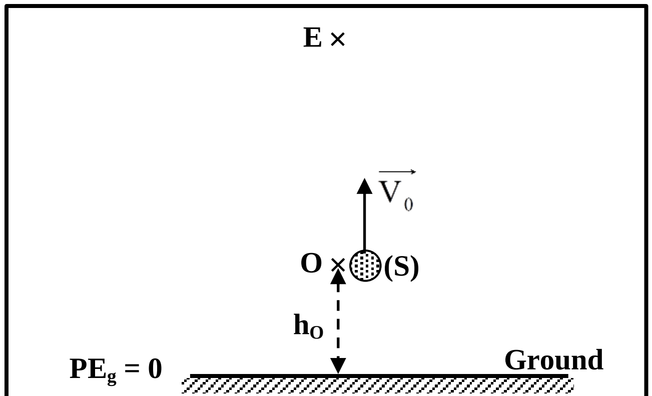
Exercise 1 (7 points) Mechanical energy

From a point O at a height h_O above the ground, a stone (S), considered as a particle of mass m = 0.1 kg, is launched vertically upwards with an initial velocity $\overrightarrow{V_0}$ as shown in document 1.

An appropriate device allows to register the gravitational potential energy (PE_g) of the system (stone – Earth) and the kinetic energy (KE) of the stone at the points O, A, B, C, D, and E during the upward motion of the stone. The results are tabulated in document 2.

Take:

- the ground as a reference level for gravitational potential energy;
- $g = 10\ m/s^2$.



Doc. 1

	O	A	B	C	D	E
PE_g (J)	2	3	4	5	6	7
KE (J)	5	4	3	2	1	0

Doc. 2

1- Indicate the value of the gravitational potential energy of the system (stone – Earth) at O.
2- Deduce the initial height h_O.
3- Determine the magnitude V_0 of the velocity $\overrightarrow{V_0}$.
4- E is the highest point attained by (S). Justify.
5- Determine, relative to the ground, the maximum height reached by (S). Deduce the distance OE.
6- Calculate the mechanical energy of the system (stone – Earth) at the points O, C, and E. Conclude.
7- Deduce the speed of (S) as it hits the ground.

Exercise 2 (7 points) Nuclear reactions: fission and fusion

The aim of this exercise is to show some of the advantages and the disadvantages of fission and fusion nuclear reactions.

1- Nuclear fission

The most commonly nuclide used in nuclear fission reactions is the uranium-235.

One of the possible nuclear reactions of uranium-235 is the following: ${}^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{90}_{36}Kr + {}^{142}_{56}Ba + y\ {}^{1}_{0}n$.

Given: $1u = 1.66 \times 10^{-27}$ kg; Speed of light in vacuum: $c = 3 \times 10^8$ m/s.

1.1) Calculate the value of "y" indicating the used law.
1.2) This reaction leads to a chain reaction. Justify.
1.3) The mass defect that occurs during the above nuclear reaction is $\Delta m = 0.177755$ u.
1.3.1) Determine the energy liberated by the fission of one nucleus of uranium-235.
1.3.2) The mass of one nucleus of uranium-235 is 3.9×10^{-22} g. Show that the energy liberated by the fission of 1 g of uranium-235 is $E_1 = 6.809 \times 10^{10}$ J.

2- Nuclear fusion

When a deuterium nucleus $^{2}_{1}H$ collides with a tritium nucleus $^{3}_{1}H$ at a high speed, they give a stable nucleus and a neutron, as in the following nuclear equation: $^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$.

The energy liberated by the fusion of 1 g by a mixture formed of $^{2}_{1}H$ and $^{3}_{1}H$ is $E_2 = 3.42 \times 10^{11}$J.

2.1) The above nuclear reaction is fusion. Justify.

2.2) The nuclei deuterium $^{2}_{1}H$ and tritium $^{3}_{1}H$ need a high speed to undergo fusion reaction. Why?

2.3) Indicate, by comparing E_2 to E_1, which of the two nuclear reactions (fission or fusion) is more interesting.

3- Utilization

Specify which one of the two nuclear reactions (fission or fusion) is used in the production of electric energy.

Exercise 3 (6 points) Celestial events in 2018

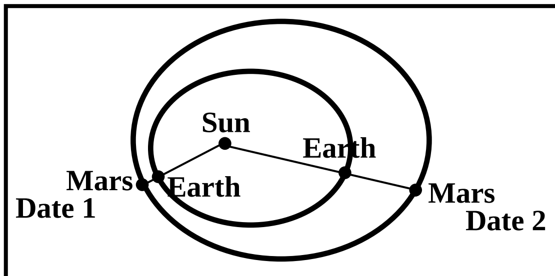
During the year 2018 many celestial events are expected, including Mars at opposition and nighty shooting stars.

- **Mars at opposition (friday, July 27)**
  Mars is at opposition when the Sun, Earth, and Mars are aligned in this order. On friday, July 27, Mars will be very easily observable in the sky, since its distance to the Earth will be minimal.
  Mars' opposition occurs approximately every two years, as Mars revolves around the Sun in an orbit larger than that of the Earth. A Martian year (Mars' year) is thus almost twice as long as a terrestrial year.
- **Nighty shooting stars (the night of 11^{th} - 12^{th} August)**
  As every year, the orbit of the Earth will cross the clouds of cometary dust scattered by the comet "Swift-Tuttle". As they enter the Earth's atmosphere, the dust will burn and give us a stream of shooting stars.

Doc. 3

1- Document 3 shows two celestial events. Indicate these two events and the date of each one.

2- Document 4 represents a simplified diagram of the trajectories of the Earth and Mars around the Sun, as well as Mars' opposition at two different dates (date 1 and date 2).



Doc. 4

2.1) Indicate the shape of the trajectories described by the planets around the Sun.

2.2) On July 27, 2018, Mars' opposition corresponds to date 1 and not to date 2. Pick out from document 3 the expression that justifies this statement.

3- Pick out from document 3 the statement that permits to conclude that the Martian year is almost double than the Earth's year.

4- Document 3 mentions the comet "Swift-Tuttle".

4.1) Name the three main parts of a comet.

4.2) Indicate the part of a comet that contains cometary dust.

4.3) Using the information in document 3, explain the process of formation of shooting stars.

Exercise 1 (7 points) Mechanical Energy

Part	Solution	Mark
1	$PE_{gO} = 2$ J	0.25
2	$PE_{gO} = mgh_O$; $h_O = \frac{2}{0.1\times10} = 2$ m	1.25
3	At O, KE = 5 J. $KE_O = \frac{1}{2}mV_O^2$; $V_O^2 = \frac{2\times5}{0.1} = 100$ then $V_O = 10$ m/s	0.25 0.5 / 0.5
4	(S) reaches the maximum height when V = 0, then KE = 0 J so at E.	0.5
5	$PE_{gE} = 7$ J. $PE_g = mgh_{max}$; $h_{max} = \frac{7}{0.1\times10} = 7$ m. Then OE = 7 – 2 = 5 m	0.75 0.25
6	$ME = PE_g + KE$. $ME_O = 7$ J, $ME_C = 7$ J, $ME_E = 7$ J. ME = constant / no friction acts on (S) during its motion.	0.5 0.75 0.5
7	ME = 7 J. at ground $PE_g = 0$; then $ME = KE_{ground} = 7$ J. $KE_{ground} = \frac{1}{2}mV_{ground}^2$; $V_{ground}^2 = \frac{2\times7}{0.1} = 140$ then $V_{ground} = 11.83$ m/s	0.25 / 0.25 0.5

Exercise 2 (7 points) Nuclear reaction: Fission and Fusion

Part			Solution	Mark
1	1.1		Using the law of conservation of mass number: 235 + 1 = 90 + 142 + y (1) then y = 4.	0.5 0.5
	1.2		Since this fission reaction gives 4 neutrons.	0.5
	1.3	1.3.1	$E = \Delta mc^2 = 0.177755 \times 1.66\times10^{-27} \times (3\times10^8)^2 = 2.66\times10^{-11}$ J.	0.5 / 0.5 / 0.5
		1.3.2	3.9×10^{-22}g $\rightarrow 2.66\times10^{-11}$J 1g $\rightarrow E_{total}$ then $E_{total} = 6.809\times10^{10}$J.	1
2	2.1		Since two light nuclei combine and give a heavier one.	1
	2.2		they need a high speed since the two nuclei are positively charged, or they need a high speed to overcome the electrostatic repulsion between the nuclei.	0.5
	2.3		$E_1 = 6.809 \times 10^{10}$ J, $E_2 = 3.42 \times10^{11}$J. $\frac{E_2}{E_1} = 5$ then E_2 is larger than E_1. Then the nuclear fusion is more interesting than the nuclear fission.	1
3			The fission reaction is used in the production of electricity since it can be controlled.	0.5

Exercise 3 (6 points) Celestial events in 2018

Part		Solution	Mark
1		First event: March at opposition Friday July 27 Second event: Nights of shooting stars night of August 11 to 12	0.5 / 0.25 0.5 / 0.25
2	2.1	Elliptical trajectory	0.5
	2.2	"its distance to the Earth will be minimal"	0.5
3		"the Red Planet gravitates around the Sun in a larger orbit than the Earth"	0.5
4	4.1	• The nucleus • The coma • the tails	0.5 0.5 0.5
	4.2	Yellow tail	0.5
	4.3	If cometary dusts enter the Earth atmosphere, they burn and form shooting stars	1