وزارة التربية والتعليم العالي
المديرية العامة للتربية
دائرة الامتحانات

امتحانات الشهادة الثانوية العامة
فرع العلوم العامة

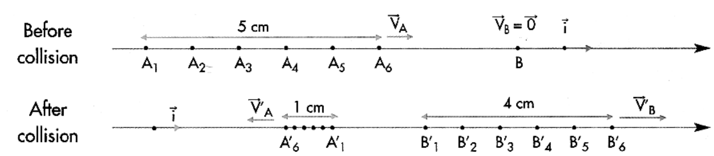
دورة سنة 2002 الاستثنائية

مسابقة في مادة الفيزياء المدة: ثلاث ساعات	الاسم: الرقم:

This exam is formed of four obligatory exercises in four pages
The use of non-programmable calculators is allowed

<u>First Exercise</u> (7 points) Collision and the laws of conservation

In order to study the collision between two bodies, we use a horizontal air table that is equipped with a launcher and two pucks (A) and (B) of respective masses $m_A = 0.2$ kg and $m_B = 0.3$ kg.



(A), thrown with the velocity $\vec{V}_A = V_A\,\vec{i}$, enters in a head-on collision with (B), initially at rest. (A) rebounds with the velocity $\vec{V}'_A = V'_A\,\vec{i}$, and (B) is projected with the velocity $\vec{V}'_B = V'_B\,\vec{i}$.
The figure below shows, in real dimensions, a part of the dot-prints, that register the positions of the centers of masses of (A) and (B), obtained when the time interval separating two successive dots is $\tau = 20$ ms.

A) Law related to the linear momentum

I) 1) Show, using the above dot-prints, that the velocities V_A, V'_A and V'_B are constant and calculate the algebraic values $\vec{V}_A$, $\vec{V}'_A$ and $\vec{V}'_B$.

2) Determine the linear momentums $\vec{P}_A$ and $\vec{P}'_A$ of the puck (A), before and after collision respectively and that $\vec{P}'_B$ of the puck (B) after collision.

3) Deduce the linear momentums, $\vec{P}$ and $\vec{P}'$, of the center of mass of the system [(A) and (B)] before and after collision respectively.

4) Compare $\vec{P}$ and $\vec{P}'$ then conclude.

II) 1) Name the forces acting on the system [(A), (B)].

2) What is the value of the resultant of these forces?

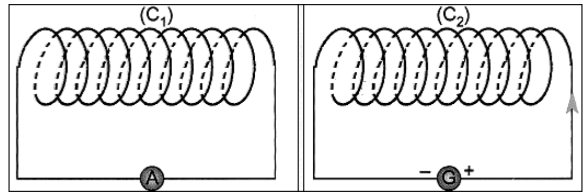
3) This result agrees with the conclusion of (I - 4). Why?

B) **Law related to the kinetic energy**

1) Calculate the kinetic energy of the system [(A), (B)] before and after collision.

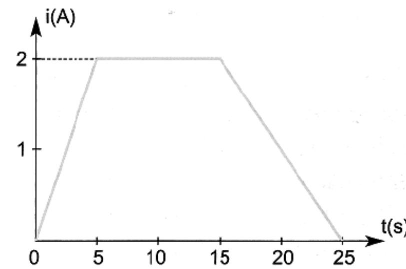
2) Deduce the nature of this collision.

Second Exercise (7 points) The transformer



The purpose of this exercise is to study the principle of functioning of an ideal transformer and its role.
Consider two coils, (C_1) of 1000 turns and (C_2) of 500 turns; the surface area of each of the turns of (C_1) and (C_2) is 100 cm^2.

A) Principle of functioning



The coil (C_1) is connected to a sensitive ammeter (A) and the coil (C_2) is connected across a generator thus forming two closed circuits. (Fig. 1)
The coil (C_2) carries then a current i that varies with time as shown in the graph of figure 2. As a resultat, (C_2) produces, through (C_1), a magnetic field $\vec{B}$ supposed uniform of magnitude $B = 2\times10^{-3}\, i$ (B in T and i in A).

1) Give the expression of the magnetic flux crossing (C_1) in terms of i.
2) Give the expression of e, the e.m.f. induced in (C_1).
3) Find the values of e for $0s \le t \le 25s$.
4) Trace the graph giving the variation of e as a function of time t for $0s \le t \le 25s$.
   Scale: on the time axis: $1cm \rightarrow 5$ s and on the axis of e: $1cm \rightarrow 4$ mV.
5) Draw again figure 1 and indicate, using Lenz's law, the direction of the current induced in (C_1), i the interval of time $0s \le t \le 5s$.

B) Role

The coils (C_1) and (C_2), disconnected from the preceding circuit, are used to construct an ideal transformer (T) using a convenient iron core. (C_1) and (C_2) are respectively the primary and the secondary.

1) We connect across (C_1) a sinusoidal alternating voltage of effective value $V_1 = 220$ V. A voltmeter, in AC mode connected across (C_2), reads a value V_2.
   a) Give a simplified diagram of (T).
   b) Does (T) act as a step-up or a step-down transformer? Justify your answer and calculate V_2.

2) A lamp, connected across the terminals of (C_2), carries a current of effective value $I_2 = 1$ A. Calculate the effective current I_1 carried by the coil (C_1).

Third exercise (6 points) Nuclear fission

Given: mass of a neutron: $m_n = 1.00866$ u

mass of a 235 uranium nucleus : $m(^{235}U) = 234.99342$ u

mass an iodine nucleus A: $m(^{A}I) = 138.89700$ u

mass of a 94 yttrium nucleus 94: $m(^{94}Y) = 93.89014$ u

$1\ u = 1.66054 \times 10^{27}$ kg $= 931.5$ MeV/c^2.

1 eV$= 1.6 \times 10^{-19}$ J

In a nuclear power station, the fissionable fuel is made up of 235 uranium nuclei. The nuclei that undergo a nuclear reaction must have been bombarded with a thermal neutron.

1) One of the possible reactions that the uranium 235 undergoes has the form of:

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{A}_{53}I + ^{92}_{Z}Y + 3^{1}_{0}n + \gamma .$$

a) The 235 uranium nucleus is fissionable. Why?

b) The nuclear reaction that the 235 uranium nucleus undergoes is said to be provoked. A provoked reaction is one of two types of nuclear reactions. Name the other type and tell how it can be distinguished from the other.

c) Determine the values of A and Z specifying the supporting laws.

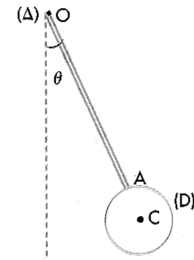
d) Calculate the energy liberated during the preceding reaction.

In what form does this liberated energy appear?

2) The nuclear power station converts 30% of the liberated energy into electrical energy.

Calculate the mass of 235 uranium consumed by the power station during one day if the electric power it supplies is 6×10^{8} W.

<u>Fourth exercise</u> (7½points) Clock pendulum



A clock pendulum may be represented by a homogeneous disk (D), of center C, fixed at the extremity A of a homogeneous rod OA.

A) Characteristics of the motion of the clock pendulum

In this part, friction is neglected.

The clock pendulum is a compound pendulum that may oscillate around a horizontal axis (Δ) passing through O (figure). During oscillations of small amplitude θ_m of proper period T_o, the pendulum passes through the equilibrium position with an angular speed of 0.3 rd/s.

Given: OA = 100 cm; g = 10 m/s^2; radius of the disk AC = 10 cm;

π = 3.14; mass of the rod = 0.5 kg; mass of the disk = 1 kg;

moment of inertia of the clock pendulum about (Δ) is: I = 1.38 kg.m^2.

1) a) Specify the equilibrium position of the pendulum.

b) Calculate the angular momentum of the pendulum while passing through the equilibrium position.

c) Determine the sum of the moments of the forces acting on the pendulum while passing through the equilibrium position.

d) Apply the theorem of angular momentum to determine the value of the angular acceleration of the pendulum while passing through the equilibrium position.

Deduce that the maximum angular speed of the pendulum is 0.3rd/s.

2) a) Show that the center of mass G of the pendulum is at a distance OG = 90 cm from O.

b) Determine the mechanical energy of the system [pendulum, Earth) for any angular elongation θ. Take the horizontal plane passing through G_o, the center of mass of the pendulum in its equilibrium position, as a gravitational potential energy reference.

c) This mechanical energy is conserved. Why? Deduce the value of θ_m.

d) Determine the differential equation that describes the periodic motion of the pendulum.

Calculate the value of T_o.

B) Driving the oscillations of the clock pendulum

In fact, the pendulum performs oscillations of pseudo-period T. If the motion of the pendulum is not driven, the oscillations tend to be damped.

1) Is the pseudo-period T greater, equal or smaller than T_o?

2) Why do the oscillations of the pendulum tend to be damped?

3) The driving of the oscillations is done by the very slow descending of a solid (S) of mass M = 2 kg. Every week, (S) descends by a height h = 1.5 m and is raised back to its initial position within 10 seconds by means of an electric motor.

Calculate the average power of the electric motor

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Question I (07 points)		
A-I-1.	Each puck (before and after collision) cover regular distances during equal time intervals: $v_A = \frac{A_1A_6}{5\,\tau} = \frac{5 \times 10^{-2} m}{5 \times 20 \times 10^{-3} s} = 0.5 m/s$, so $\overrightarrow{v_A} = 0.5\,\vec{\imath}\,(m/s)$; $\overrightarrow{v'_A} = -0.1\,\vec{\imath}\,(m/s)$; $\overrightarrow{v'_B} = +0.4\,\vec{\imath}\,(m/s)$;	**0.25** **0.5** **0.25** **0.25**
A-I-2.	$\overrightarrow{p_A} = m_A\overrightarrow{v_A} = 0.1\,\vec{\imath}\,(kg.m/s)$; $\overrightarrow{p'_A} = -0.02\,\vec{\imath}\,(kg.m/s)$; $\overrightarrow{p'_B} = 0.12\,\vec{\imath}\,(kg.m/s)$;	**0.5** **0.25** **0.25**
A-I-3.	$\vec{p} = 0.1\,\vec{\imath}\,(kg.m/s)$; $\overrightarrow{p'} = 0.1\,\vec{\imath}\,(kg.m/s)$;	**0.5** **0.25**
A-I-4.	$\vec{p} = \overrightarrow{p'}$; Thus, the linear momentum of the system $[(A),(B)]$ is conserved.	**0.5**
A-II-1.	The forces acting on the system $[(A),(B)]$ are the weight of each $\overrightarrow{w_A}$ & $\overrightarrow{w_B}$ and the normal reactions exerted by the support $\overrightarrow{N_A}$ & $\overrightarrow{N_B}$.	**0.5**
A-II-2.	The resultant force is: $\sum \overrightarrow{F_{\text{ext}}} = \left(\overrightarrow{w_A} + \overrightarrow{N_A}\right) + \left(\overrightarrow{w_B} + \overrightarrow{N_B}\right) = \vec{0}$	**1**
A-II-3.	If $\sum \overrightarrow{F_{\text{ext}}} = \vec{0}$, then $\frac{d\vec{P}}{dt} = \vec{0}$;	**0.5**
B-1.	$KE_{\text{just before collision}} = 0.025J$ $KE_{\text{just after collision}} = 0.025J$	**1**
B-2.	The collision is elastic.	**0.5**

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Question II (07 points)		
A-1.	The magnetic flux crossing (C_1): $\phi = N_1 B\, S_1 \cos\theta$ where $\theta = (\vec{n}, \vec{B}) = 0$; $\phi = 1000 \times 2 \times 10^{-3} i \times 100 \times 10^{-4} \times \cos 0 = 0.02\, i$ (ϕ in Wb & i in A)	**0.25** **0.5**
A-2.	Faraday's law: $e = -\frac{d\phi}{dt} = -0.02\frac{di}{dt}$ (where i in A & e in V)	**0.5**
A-3.	For $0 \le t \le 5s$, $e_1 = -0.02 \times \frac{(2-0)}{(5-0)} = -8mV$. For $5s \le t \le 15s$, $e_2 = 0$. For $15s \le t \le 25s$, $e_3 = 4mV$	**0.5** **0.25** **0.5**
A-4.	Graph	**0.5**
A-5.	For $0 \le t \le 5s$, the current increases then the strength of the magnetic field $\vec{B}$. According to Lenz's law, the induced magnetic field $\vec{B_i}$ should act to oppose this change. Then $\vec{B_i}$ is horizontal to the right. By Right Hand Rule, the current induced in (C_1) is clockwise Diagram	**0.5** **0.5**
B-1.a)	Setup	**0.5**
B-1.b)	Law of voltages: $$\frac{U_2}{220V} = \frac{500}{1000};$$ Then $U_1 = 110V$.	**1**
B-2.	Law of currents: $$\frac{1A}{I_1} = \frac{1000}{500};$$ Then $I_1 = 0.5A$	**1**

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Question III (06 points)		
1.a)	The uranium nucleus ^{235}U bombarded by a thermal neutron, was divided into two lighter nuclei.	**0.5**
1.b)	The spontaneous radioactivity is another type of nuclear reactions. A provoked nuclear reaction needs the intervention of an external agent whereas a spontaneous nuclear reaction occurs naturally.	**0.25** **0.5**
1.c)	According to Soddy's laws: Conservation of mass number: $1 + 235 = A + 94 + 3 \times 1$, then $A = 139$; Conservation of charge number: $0 + 92 = 53 + Z$, then $Z = 39$;	**0.5** **0.5**
1.d)	The mass lost during this reaction: $m_\ell = \left[m({}_0^1n) + m({}_{92}^{235}U)\right] - \left[m({}_{53}^{A}I) + m({}_{Z}^{94}Y) + 3m({}_0^1n)\right]$; Then, $m_\ell = 0.18806u$ The energy liberated by one reaction: $E_\ell = m_\ell c^2 = 0.18806 \times 931.5MeV = 175.2MeV.$ This energy appears as: - kinetic energy carried by the emitted neutrons and daughter nuclei. - radiant energy carried by γ-radiation.	**0.5** **0.5** **0.5**
2.	The nuclear energy delivered by the uranium in one day: $E_{\text{nuclear}} = P_{\text{nuclear}} \times \Delta t = 2 \times 10^9 \times 24 \times 3600 = 1.728 \times 10^{14}J.$ 1 fission $\xrightarrow{\text{mass of}} 234.99342 \times 1.66 \times 10^{-27}kg \xrightarrow{\text{liberates}} 175.2 \times 1.6 \times 10^{-13}J$ $m \xrightarrow{\text{liberates}} 1.728 \times 10^{14}J$ The daily consumption of uranium is: $m = 2.4kg.$	**0.25** **0.5** **1** **0.5**

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Question IV (7.5 points)		
A-1.a)	$\theta = 0$.	**0.25**
A-1.b)	Then, $\sigma = 1.38 \times 0.3 = 0.414\ kg.m^2.\text{rad}/s$.	**0.5**
A-1.c)	$\text{M}_{\vec{W}/(\Delta)} = 0$ (meets the axis) and $\text{M}_{\vec{R}/(\Delta)} = 0$ (applied on axis);	**0.5**
A-1.d)	Theorem of angular momentum: $\sum \text{M}_{\vec{F}/(\Delta)} = \frac{d\sigma}{dt}, \theta'' = \frac{d\theta}{dt} = 0, \text{thus}, \theta'_{\text{max}} = 0.3\text{rad/s}$	**0.75**
A-2.a)	$\overline{OG} = \frac{m\overline{OG}_{\text{rod}} + m'\overline{OC}}{m+m'} = 90cm$	**1**
A-2.b)	$ME = KE + GPE = \frac{1}{2}I\theta'^2 + (m+m')g\ a\ (1-\cos\theta)$.	**0.5**
A-2.c)	In the absence of friction, the mechanical energy of the system is conserved: We get: $\frac{1}{2}I\theta_0'^2 = (m+m')g\ a\ (1-\cos\theta_m)$; Then, $\cos\theta_m = 1 - \frac{I\theta_0'^2}{2(m+m')ag}$; Thus, $\theta_m \approx 5.5^0$	**0.5** **0.5**
A-2.d)	$\frac{d(ME)}{dt} = 0$, so $I\ \theta'\theta'' + (m+m')ga\theta' \sin\theta = 0$; We get: $\theta'' + \frac{(m+m')ga}{I}\theta = 0$ $T_0 = \frac{2\pi}{\omega_0} = 2\pi\sqrt{\frac{I}{(m+m')g\ a}} \approx 2s$.	**1**
B-2.a)	T is always larger than the proper period T_0.	**0.5**
B-2.b)	The decrease in the mechanical due to dissipative forces.	**0.5**
B-2.c)	$P_{av} = \frac{E_{\text{dissipated}}}{\Delta t} = 3W$.	**1**