LEBANESE UNIVERSITY
FACULTY OF ENGNEERING

الجامعة اللبنانية
كلية الهندسة

Entrance exam 2024-2025 **July 2024**
Physics (A) **Duration 120 min**

In order to eliminate random answer strategies, **each correct answer is rewarded by 1.25 point**, while **each wrong answer is penalized by the withdrawal of 0.5 point**.

Take g = 10 m/s^2 where necessary.

Exercise 1: Energy levels of the hydrogen atom (17.5 pts)

The energies of the different levels of the hydrogen atom are given by the relation:

$E_n = -\frac{E_0}{n^2}$, where E_0 = 13.60 eV and n a positive integer. All the wavelengths are given in vacuum.

For this atom, we associate many spectral line series relative to the absorption or to the emission.

Given: h = 6.62×10^{-34} J.s; c = 3.00×10^8 m/s; 1 eV = 1.60×10^{-19} J; 1 nm = 10^{-9} m; limits of the visible spectrum: 400 nm ≤ $\lambda_{visible}$ ≤ 800 nm.

A- Particular questions. Photon-atom interaction (5½)

1. Calculate, in eV, the energies of the first three excited states. (¾)

2. The hydrogen atom is found in the ground state.

2.1. Determine, in J, the ionization energy Wi of the hydrogen atom. (1)

2.2. The atom receives now a photon of wavelength λ_i. The atom is thus ionized and the extracted electron is at rest. Calculate λ_i. (1)

2.3. Determine the maximum wavelength of the photon that is able to excite this atom. (1½)

2.4. The hydrogen atom is hit by a photon of wavelength λ_0 = 206.20 nm.

2.4.1. Will this photon be absorbed? Justify. (¾)

2.4.2. Indicate then the final state of this atom. (½)

B- Spectral line series of the hydrogen atom

B-I Balmer series (4)

We consider the Balmer series that is characterized by the transitions from the energy levels E_P (p > 2) to the energy level E_2 (n = 2). To each transition p→2 corresponds a spectral line of wavelength $\lambda_{p\to2}$.

1. Show that the expression giving, in nm, the wavelength $\lambda_{p\to2}$ is: $\lambda_{p\to2} = 365.07(\frac{p^2}{p^2-4})$. (1½)

2. The analysis of the emission spectrum reveals the presence of the visible radiations denoted by (H_α), (H_β), (H_γ) and (H_δ), respectively from the greatest wavelength to the smallest.

2.1. Calculate, in nm, the values of the respective wavelengths λ_α, λ_β, λ_γ and λ_δ. (1)

2.2. H_α radiation, of wavelength λ_α, corresponds to one extremity of the Balmer series.

2.2.1. Determine the wavelength λ_e of the radiation which corresponds to the other extremity. (1¼)

2.2.2. This radiation is not visible. What type of radiation (IR or UV) does it belong to? (¼)

B-II Paschen series (1¼)

1. Determine the wavelength $\lambda_{4\to3}$, due to the transition from the level n = 4 to the level n = 3. (1)

2. What type of radiation (IR or UV) does it belong to? (¼)

B-III Lyman absorption series of the hydrogen atom (4¾)

In the Lyman absorption series, the atom passes from the ground state to an excited energy level E_n by absorbing a photon of energy E_{ph}.

1. Determine, in eV, the expression of the energy E_{ph} of the absorbed photon in terms of n. (¾)

2. Deduce that the wavelength λ of a spectral line of the Lyman absorption series is given by the relation:

$\frac{1}{\lambda} = 1.097\times10^7\ (1-\frac{1}{n^2})$, where λ is expressed in m^{-1}. (1)

3. A little dense hydrogen atoms cloud, assumed to be found in the ground state, is illuminated by a continuous polychromatic UV radiation containing all the wavelengths of the interval λ ∈ [96 nm;100 nm]. The analysis of the radiation leaving this cloud shows a strong absorption of a single wavelength of the original radiation, while the rest of the spectral interval did not undergo any absorption.

3.1. By absorbing this radiation, the atom passes to the level n of energy E_n. Determine the minimum value n_{min} of n as well as its maximum value n_{max}. (2)

3.2. Deduce the value of n. (½)

3.3. Calculate the value of λ. (½)

C- Electron-atom interaction (2)

Monokinetic electrons (all the electrons having the same kinetic energy) KE= 12.60 eV, collide with the hydrogen atoms cloud, assumed to be found in the ground state.

1. Determine the maximum excited state of a hydrogen atom. (1½)

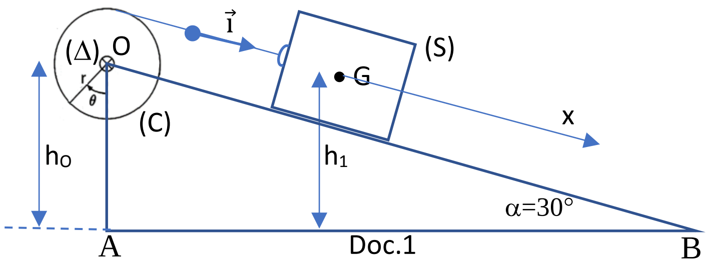
2. Deduce, in eV, the kinetic energy of an electron after its interaction with a hydrogen atom. (½)

Exercise 2: Determination of the moment of inertia of a pulley (17.5 pts)

We have a homogeneous pulley (C), of mass m = 400 g, of radius r = 10 cm and of moment of inertia I_0 relative to its axis (Δ) passing through its center of inertia O. The aim of this exercise is to determine I_0.

A- First method

A rope of negligible mass, fixed and wound on the pulley, is attached to a solid (S) of mass M = 100 g which can slide on the line of greatest slope of a plane inclined by an angle α = 30° with respect to the horizontal. We neglect the friction due to the axis (Δ) and we assume that the inclined plane exerts on (S) a friction force $\vec{f}$ of constant value f.



Doc.1

I- Determination of f

We disconnect the solid (S) from the rope and let it slide along the line of greatest slope of the inclined plane. Starting from rest, after a duration Δt = 1 s, (S) reaches a velocity of value V_1 = 3.6 m/s.

1. At the end of the duration Δt, the variation $\Delta\vec{P}$ of the linear momentum of (S) is:

a) $\Delta\vec{P} = 3.6\,\vec{i}$; **b)** $\Delta\vec{P} = 0.36\,\vec{i}$; **c)** $\Delta\vec{P} = -\,0.36\,\vec{i}$.

2. Applying Newton's second law $\Sigma\vec{F}_{ext} = \frac{d\vec{P}}{dt}$ and taking $\frac{d\vec{P}}{dt} = \frac{\Delta\vec{P}}{\Delta t}$, we find that the value of f is:

a) f = 1.4 N ; b) f = 0.014 N ; **c)** f = 0.14 N.

II- Determination of I_0

We attach (S) again to the rope and, at the instant t_0 = 0, the center of inertia G of (S), which is initially at a height h_1, starts from rest and the pulley begins to rotate around its axis (Δ). At an instant t, the abscissa of G is x, the algebraic measure of its velocity is $V = \frac{dx}{dt}$, the angular abscissa of the pulley is θ and its angular velocity is $\theta' = \frac{d\theta}{dt}$. Take :

- the horizontal plane containing AB as the reference level for the gravitational potential energy;
- the rope does not slip on the groove of the pulley.

1.1. At an instant t, the expression of the mechanical energy of the system [(C), (S), rope, Earth] is:

a) $ME = ½(M + \frac{I_0}{r^2})\,V^2 + m\,g\,h_O + M\,g\,(h_1 - x\sin\alpha)$; **b)** $ME = ½(M + \frac{I_0}{r^2})\,V^2 + m\,g\,h_O - M\,g\,x\sin\alpha$;

c) $ME = ½(M + \frac{I_0}{r^2})\,V^2 + m\,g\,h_O - M\,g\,(h_1 - x\sin\alpha)$.

1.2. Let $m\vec{g}$ be the weight of (C), $M\vec{g}$ the weight of (S), $\vec{R}_\Delta$ the reaction of the axis (Δ), $\vec{T}$ the tension of the rope exerted on (S) and $\vec{N}$ the normal reaction of the inclined plane. The external forces acting on the system [(C), (S), rope, Earth] are then:

a) $m\vec{g}$, $M\vec{g}$, $\vec{R}_\Delta$, $\vec{T}$, $\vec{N}$ and $\vec{f}$. **b)** $\vec{R}_\Delta$, $\vec{T}$, $\vec{N}$ and $\vec{f}$; **c)** $\vec{R}_\Delta$, $\vec{N}$ and $\vec{f}$.

1.3. The power $P(\Sigma\vec{F}_{ext})$ of the external forces exerted on the system [(C), (S), rope, Earth] is:

a) $P = (Mg\sin\alpha - f)\cdot V$; **b)** $P = - f\cdot V$; **c)** $P = Mg\sin\alpha\cdot V$.

1.4. Knowing that $P(\Sigma\vec{F}_{ext}) = \frac{dME}{dt}$ (Mechanical energy theorem), we find that the expression giving the algebraic measurement a of the acceleration of (S) is:

a) $a = \frac{Mg\sin\alpha - f}{\left(M + \frac{I_0}{r^2}\right)}$; **b)** $a = \frac{-Mg\sin\alpha + f}{\left(M + \frac{I_0}{r^2}\right)}$; **c)** $a = \frac{Mg - f}{\left(M + \frac{I_0}{r^2}\right)}$.

2. We notice that after 5 s, (S) reaches a speed V = 6 m/s.

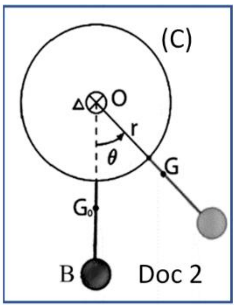
2.1. The value a, supposed constant, of the acceleration of (S) is:

a) $a = 0.83\ m/s^2$; **b)** $a = 1.20\ m/s^2$; **c)** $a = 1.30\ m/s^2$.

2.2. The value of I_0 is then:

a) $I_0 = 0.006\ kg\cdot m^2$; **b)** $I_0 = 0.004\ kg\cdot m^2$; **c)** $I_0 = 0.002\ kg\cdot m^2$

B- Second method



Doc 2

We remove the rope and the solid (S) and we attach to the pulley (C), using a rod OB of negligible mass, a small ball (B) of mass m' = 600 g at the distance OB = d = 20 cm from the center O of the pulley. Let a = OG be the distance between O and the center of gravity G of the set [(C), rod, (B)], denoted by (Z). (Doc 2)

Friction forces are neglected and the reference level for the gravitational potential energy is the horizontal plane passing through O.

1. We find that:

1.1. the distance a = OG has the value:

a) a = 0.12 m; **b)** a = 0.24 m; **c)** a = 0.06 m.

1.2. the moment of inertia I of (Z) relative to the axis (Δ) has, in $kg.m^2$, the expression:

a) $I = I_0 + 0.012$; **b)** $I = I_0 + 0.024$; **c)** $I = I_0 - 0.024$.

2. We move (Z), thus constituted, by an angle $\theta_0 = 60°$ from its stable equilibrium position, schematized by OG_0, then we release it from rest at the instant $t_0 = 0$. It begins to perform, around (Δ), a back and forth rotational motion on either side of OG_0. At an instant t, its position is identified by its angular elongation θ made by the vertical passing through O with OG, and its angular velocity is $\theta' = \frac{d\theta}{dt}$.

2.1. At an instant t, the expression of the mechanical energy ME of [(Z), Earth] is:

a) $ME = \frac{1}{2}I\cdot\theta'^2 - (m + m')g\cdot d\cdot\cos\theta$; **b)** $ME = \frac{1}{2}I\cdot\theta'^2 - (m + m')g\cdot a\cdot\sin\theta$;

c) $ME = \frac{1}{2}I\cdot\theta'^2 - (m + m')g\cdot a\cdot\cos\theta$.

2.2. The value of the mechanical energy ME_0 of the considered system at the instant $t_0 = 0$ is:

a) $ME_0 = 0.60$ J; **b)** $ME_0 = - 0.60$ J; **c)** $ME_0 = - 0.70$ J.

2.3. Knowing that the absolute value of the angular velocity of (Z) when it passes through its equilibrium position is $|\theta'_e| = 6.79$ rad/s, then the value of the moment of inertia I of (Z) is:

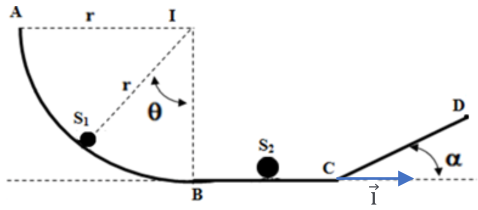
a) $I = 0.029\ kg\cdot m^2$; **b)** $I = 0.026\ kg\cdot m^2$; **c)** $I = 0.022\ kg\cdot m^2$.

2.4. The value of I_0 is then:

a) $I_0 = 0.002\ kg\cdot m^2$; **b)** $I_0 = 0.004\ kg\cdot m^2$; **c)** $I_0 = 0.006\ kg\cdot m^2$.

Exercise 3: Conservation and non-conservation of mechanical energy (10 pts)

We intend to study the motion of two solids (S_1) and (S_2), assumed to be point-like, of respective masses m_1 = 30 g and m_2 = 60 g along a path ABCD located in a vertical plane and represented on the adjacent document. The path AB is circular with center I and radius r; the path BC is horizontal. Friction forces are negligible along the path ABC. The path CD is the line of greatest slope of a plane inclined by an angle α = 9.6° with the horizontal and (S_2) undergoes, on this path, a friction force $\vec{f}$ of value f = 0.20 N. The positive direction is from B to C, (C, $\vec{i}$).



The solid (S_1), released from rest at point A, acquires a velocity $\vec{v}_1$ of value v_1 at B and collides with the solid (S_2) initially at rest between B and C.

1. Let v'_1 and v'_2 be the algebraic values of the respective velocities $\vec{v}'_1$ and $\vec{v}'_2$ of (S_1) and (S_2) just after the collision. After the collision, (S_1) redounds and reaches, on BA, a point N of height h_N = 1.25 cm whee its speed becomes zero and (S_2) reaches the point D, with CD = 10 cm, where its speed becomes zero.

1.1. The mechanical energy ME_1 of the system [(S_1), Earth], just after the collision, is,

a) ME_1 = 0.00375 J; **b)** ME_1 = 0.00450 J; **c)** ME_1 = 0.00250 J.

1.2. The linear momentum $\vec{P}'_1$ of (S_1), just after the collision, expressed in kg·m/s, is:

a) $\vec{P}'_1$ = -0.012 $\vec{i}$; **b)** $\vec{P}'_1$ = - 0.015 $\vec{i}$; **c)** $\vec{P}'_1$ = - 0.017 $\vec{i}$.

1.3. The variation of the mechanical energy ΔME_2 of the system [(S_2), Earth] between C and D is:

a) ΔME_2 = - 0.01 J ; **b)** ΔME_2 = - 0.02 J ; **c)** ΔME_2 = - 0.04 J.

1.4. The mechanical energy ME_2 of the system [(S_2), Earth], just after the collision, is:

a) ME_2 = 0.200 J; **b)** ME_2 = 0.250 J; **c)** ME_2 = 0.030 J.

1.5. The linear momentum $\vec{P}'_2$ of (S_2), just after the collision, expressed in kg·m/s, is:

a) $\vec{P}'_2$ = -0.060 $\vec{i}$; **b)** $\vec{P}'_2$ = + 0.060 $\vec{i}$; **c)** $\vec{P}'_2$ = + 0.045 $\vec{i}$.

2. The value v_1 of the velocity $\vec{v}_1$ of (S_1), just before the collision, is:

a) v_1 = 1.5 m/s ; **b)** v_1 = 1.7 m/s ; **c)** v_1 = 1.8 m/s.

3. The total kinetic energy $KE_{(after)}$ of the system [(S_1), (S_2)], just after the collision, is:

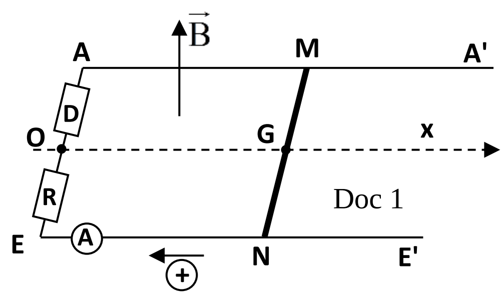
a) $KE_{(after)}$ = 0.03756 J ; **b)** $KE_{(after)}$ = 0.03635 J ; **c)** $KE_{(after)}$ = 0.03375 J.

4. The radius r of the circular path AB is:

a) r = 15.52 cm ; **b)** r = 8.41 cm ; **c)** r = 11.25 cm.

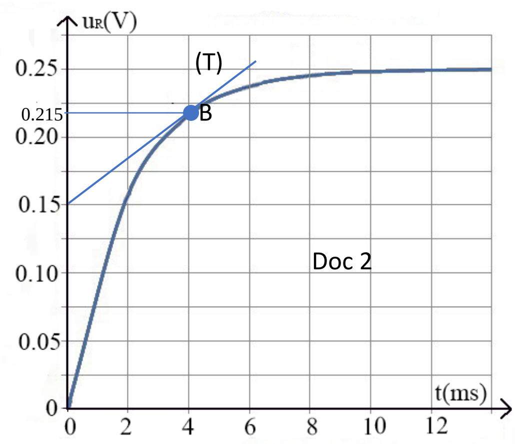
Exercise 4: Induction and self-induction (15 pts)

A metallic rod MN, of length ℓ =1 m and of negligible resistance, can move without friction on two horizontal, parallel, rectilinear and long rails AA' and EE' of negligible resistance. During its motion, it remains perpendicular to the rails. A resistor of resistance R = 10 Ω and a coil (B) of inductance L and resistance r are connected to the two rails by means of connecting wires. The set already mentioned is placed in an ascending, vertical, uniform magnetic field $\vec{B}$ of magnitude B = 0.80 T. (Doc 1)



At the instant t_0 = 0, the center of gravity G of the rod is at O. An appropriate device makes the rod move in a uniform translational motion, from left to right, with a velocity of value v = 0,50 m/s. At an instant t, G is located by its abscissa x = $\overline{OG}$ on the x'x axis.

1. At the instant t, the expression of the magnetic flux ϕ through the surface AMNE is given by:
a) $\phi = - B\ell v$; **b)** $\phi = - B\ell x$; **c)** $\phi = B\ell x$.
2.1. An induced e.m.f. E appears across the terminals N and M of the rod of value:
a) E = - 0.4 V ; **b)** E = -0.6 V ; **c)** E = 0.4 V.
2.2. At an instant t, an induced current i is carried by the circuit. The current i is:
a) in the positive direction; **b)** in the negative direction.
2.3. The algebraic value of the voltage u_{MN} between M and N is:
b) u_{MN} = -0.20 V; **b)** u_{MN} = - 0.40 V; **c)** u_{MN} = -0.60 V.
3. Starting from the instant t_1, the circuit reaches a steady state and the ammeter (A) displays I_0 = 25 mA.
3.1. Starting from the instant t_0 = 0, during the motion of the rod, a self-induced electromotive force "e" appears across the coil. At an instant t, the algebraic expression of this e.m.f. "e" is:
a) $e = - L\frac{di}{dt}$; **b)** $e = L\frac{di}{dt}$; **c)** e = 0.
3.2. In steady state, the algebraic expression of this e.m.f. "e" is:
a) $e = - L\frac{di}{dt}$; **b)** $e = L\frac{di}{dt}$; **c)** e = 0.
4. The value of the resistance r of the coil is:
a) r = 8 Ω ; **b)** r = 6 Ω ; **c)** r = 4 Ω.
5. The differential equation which describes the variation of $u_R = u_{EO}$ is given by:
a) $\frac{du_R}{dt} + \frac{R+r}{L} u_R = \frac{R \cdot u_{NM}}{L}$; **b)** $\frac{du_R}{dt} + \frac{R}{L} u_R = \frac{R \cdot u_{NM}}{L}$; **c)** $\frac{du_R}{dt} + \frac{R+r}{L} u_R = \frac{(R+r) \cdot u_{NM}}{L}$.
6. The solution of this differential equation is of the form:
a) $u_R = \frac{R \cdot u_{NM}}{r+R} (1 - e^{-\frac{Rt}{L}})$; **b)** $u_R = \frac{R \cdot u_{NM}}{r+R} (1 - e^{-\frac{(r+R)t}{L}})$; **c)** $u_R = \frac{R \cdot u_{NM}}{r} (1 - e^{-\frac{(r+R)t}{L}})$.
7. The expression of t_1 is given by:
a) $t_1 = 5\frac{r+R}{L}$; **b)** $t_1 = 5\frac{L}{r+R}$; **c)** $t_1 = 5\frac{L}{R}$.
8. The curve in document 2 shows the variation of u_R with respect to time. (T) is the tangent to the curve u_R at point B (4 ms; 0.215 V).



8.1. The slope "p" of the tangent (T) is:
a) p = 16.25 V/s ; **b)** p = 14.25 V/s ; **c)** p = 12.5 V/s.
8.2. Using document 2 and the differential equation, we find that the value of "L" is:
a) L = 0.48 H **b)** L = 0.039 H ; **c)** L = 0.034 H.

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Exercise 1: Energy levels of the hydrogen atom (17½)

Exercise 2 : Determination of the moment of inertia of a pulley (17.5 pts)

Question	a)	b)	c)
A-I-1.		X	
2.			X
A-II-1.1.	X		
1.2.			X
1.3.		X	
1.4.	X		
2.1.		X	
2.2.			X
B-1.1.	X		
1.2.		X	
2.1.			X
2.2.		X	
2.3.		X	
2.4.	X		

Exercise 3 : Conservation and non-conservation of mechanical energy (10 pts)

Question	a)	b)	c)
1.1	X		
1.2.		X	
1.3.		X	
1.4.			X
1.5.		X	
2.	X		
3.			X
4.			X

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Exercise 4 : Induction and self-induction
(15 pts)

Question	a)	b)	c)
1.		X	
2.1			X
2.2.	X		
2.3.		X	
3.1.	X		
3.2.			X
4.		X	
5.	X		
6.		X	
7.		X	
8.1.	X		
8.2.			X