وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات	امتحانات الشهادة الثانوية العامة فرع العلوم العامة	دورة سنة 2005 الاستثنائية

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

This exam is formed of 4 exercises in 4 pages numbered from 1 to 4.
The use of non-programmable calculators is allowed.

First exercise (7 pts) Moment of inertia of a disk

Consider a homogeneous disk (D) of mass m = 400 g and of radius R =10 cm.

The object of this exercise is to determine, by two methods, the moment of inertia I_0 of (D) about an axis (Δ_0) perpendicular to its plane through its center of mass G.

Neglect all friction. **Take:** $0{,}32\pi = 1$; $g = 10\ m/s^2$; $\sin\theta = \theta_{(rd)}$ for small θ .

A- First method

The disk (D) is free to rotate about the horizontal axis (Δ_0), that is perpendicular to its plane through its center G (fig.1). This disk starts from rest, at the instant $t_0 = 0$, under the action of a force $\vec{F}$ of constant moment about (Δ_0) and of magnitude M = 0,2 m.N. At the instant $t_1 = 5$ s, (D) rotates then at the rotational speed $N_1 = 80$ turns/s.

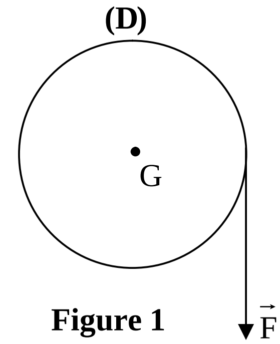


Figure 1

1) a- Give the names of the external forces acting on (D) and represent them on a diagram.
   b- Show that the resultant moment of these forces, about (Δ_0), is equal to the moment M of the force $\vec{F}$.
   c- Specify, using the theorem of angular momentum, the nature of the motion of (D).
2) a- Find the expression of the angular momentum *a* of the disk, about (Δ_0) , as a function of t.
   b- Determine the value of I_0 .

B – Deuxième méthode

The disk (D) is free to oscillate about a horizontal axis (A), perpendicular to Its plane through a point O of its periphery

We denote by I the moment of inertia of (D) about (A).We shift (D), from its equilibrium position , by a small angle θ_0 and then we release it without initial velocity , at the instant $t_0 = 0$.

The position of (D) is defined, at any instant t , by the angle θ that the axis OZ makes with OG .

$\theta' = \frac{d\theta}{dt}$ represents the angular velocity of (D) at the instant t (fig. 2).

The horizontal plane passing through the point 0 is taken *as* a gravitational potential energy reference.

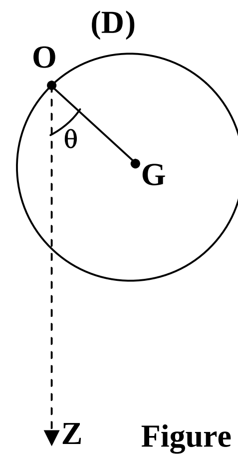


Figure 2

1) determine, at the instant t, the mechanical energy of the system [(D),Earth], in terms of I , m , g , R , θ and θ′.
2) Derive the second order differential equation that describes the oscillatory motion of (D).
3) Deduce the expression of the period T of the oscillations of (D) in terms of I , m , g and R .
4) The time taken by the compound pendulum thus formed to perform 10 oscillations is 7.7s. Determine the value of I.
5) mowing that I_0 and I are related by the relation $I = I_0 + mR^2$, find again the value of I_0 .

Second exercise (7 pts) Identification of an electric component

We intend to exploit a waveform and identify an electric component (D) of physical characteristic X. (D) may be:
- a resistor of resistance $X = R_1$
- or a capacitor of capacitance X = C
- or a coil of inductance X = L and of negligible resistance. In order to do that, we connect (D) in series with a resistor of resistance R = 400 across a generator delivering across its terminals an alternating sinusoidal voltage:

$$u_g = u_{AC} = 4\sqrt{2}\cos(100\pi t), \text{ (u in V et t in s) (fig.1).}$$

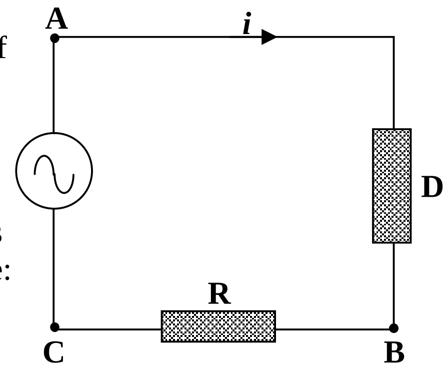


Figure 1

The circuit thus carries an alternating sinusoidal current *i*. An oscilloscope, conveniently connected, displays the waveforms time, of the voltage $u_{AC} = u_g$ on channel 1 and that of the voltage (fig.2).
The vertical sensitivity on channel 2 is 2V/div.

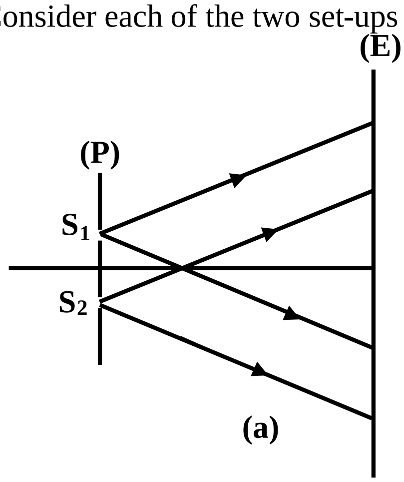
1) Redraw the figure 1 showing the connections of the oscilloscope.
2) a- Calculate the value of the period T of the voltage u_g.
   b- Determine the horizontal sensitivity of the oscilloscope.
3) a- The waveform of usc represents the "image" of the current *i*. Why?
   b- Specify the nature of the component (D). Justify your answer.

4) a- Determine the phase difference between u_{AC} and u_{BC}.
   b- Determine the maximum value I_m of the current *i*.
   c- Write the expression of *i* as a function of time .

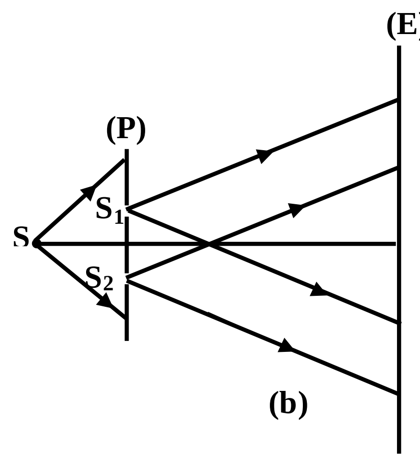
5) Show that u_{AB} may be written in the form: $u_{AB} = \frac{0,1}{100\pi X}\sin(100\pi t + \frac{\pi}{4})$
6) Applying the law of addition of voltages, determine X by giving t a particular value.

Third exercise (6 ½ pts) Interference of light

A- Conditions to obtain a phenomenon of interferences
We are going to use Young's double slit and two identical lamps.
Consider each of the two set-ups (a) and (b) drawn.



(a)



(b)

In the set-up (a), each of the slits S_1 et S_2 is illuminated by a lamp; the two lamps emit the same radiation.
In the set-up (b), S_1 et S_2 are illuminated by a lamp placed at S next to a very narrow slit parallel to S_1 and S_2; the lamp emits the same preceding radiation.
Dans le dispositif (b), S_1 et S_2 sont éclairées par une lampe placée en S et munie d'une fente très fine parallèle à S_1 et S_2 ; la lampe émet la même radiation précédente.

1- The radiation emitted by the sources S_1 and S_2 in the two set-ups (a) and (b) have a common property. What is it?

2- One property differentiates the radiations issued from S_1 and S_2 in the set-up (a) from those issued from S_1 and S_2 in the set-up (b). Specify this property.

3- The set-up (b) allows us to observe the phenomenon of interference. Why ?

B- Interference in air

We intend to perform a series of experiments about interference using Young's slits apparatus. The slits are in a plane (P), separated by a distance a , and the pattern of interference is observed on a screen (E) found at a distance D from (P).

I- Interference in air

Consider many light filters, each allowing the transmission of a specific monochromatic radiation. For each radiation of wavelength in air, we measure the distance x = 5i along which five interfringe distances extend. The results obtained are tabulated as in the table below.

λ(*en nm*)	470	496	520	580	610
x = 5i (en mm)	11,75	12,40	13,00	14,50	15,25
i (en mm)					

1) a- Complete the table.

b) i- Show that the expression of i as a function of λ is of the form $i = \alpha\lambda$ where α is a positive constant.

ii- Calculate α.

iii- Deduce the value of the ratio $\frac{D}{a}$.

2) We move (E) by 50 cm away from (P). we find that, for the radiation of wavelength λ = 496 nm

In air, five interfringe distances extend over a distance of 18.6 mm. Determine the value of D.

3) Deduce the value of a.

II – Interference in water

The radiation used now has a wavelength λ = 520 nm in air. The preceding apparatus is immersed completely in water whose index of refraction is n. The distance between the planes (E) and (P) is D and the distance between the slits is a.

1- The value of the wavelength λ of a luminous radiation changes when it passes from a transparent medium into another. Why?

2-The interference fringes in water seem closer than in air. Why?

3- In water, five interfringe distances extend over a distance of 9.75 mm. Determine the value of n.

<u>Quatrième exercice (7 pts)</u> The technetium 99

A - A bit of history...

In 1937, Pierrier and Sêgre obtained, for the first time, an isotope of technetium $^{99}_{43}Tc$ by bombarding the nuclei of molybdenum $^{98}_{42}Mo$ with an isotope of hydrogen $^{A}_{Z}H$ according to the following reaction :

$$^{98}_{42}Mo + ^{A}_{Z}H \longrightarrow ^{99}_{43}Tc + ^{1}_{0}n$$

Determine Z and A specifying the laws used.

B- Production of technetium 99 at the present time and its characteristic

The isotope $^{99}_{43}Tc$ is actually obtained in a generator molybdenum/technetium, starting from the isotope $^{99}_{42}Mo$ of molybdenum. This molubdenum is a β^- emitter.

1) Write the equation corresponding to the decay of $^{99}_{42}Mo$.
2) Determine, in MeV, the energy liberated by this decay.
3) Most of the technetium nuclei obtained are in an exited state [$^{99}_{43}Tc^*$]
   a- i) Complete the equation of the following downward transition: $^{99}_{43}Tc^* \longrightarrow ^{99}_{43}Tc + ...$
      ii) Specify the nature of the emitted radiation.
   b- The energy liberated by this transition, of value 0.14 MeV, is totally carried by the emitted radiation; the nuclei [$^{99}_{43}Tc^*$] and $^{99}_{43}Tc$ are supposed to be at rest.
      i) Determine, in u, the mass of the $^{99}_{43}Tc^*$ nucleus.
      ii) Calculate the wavelength of the emitted radiation.

C- Using technetium 99 in medicine

The isotope $^{99}_{43}Tc$ is actually often used in medical imaging. The generator molybdenum/technetium is known, in medicine, by the name " technetium cow". Also, the daily preparation of the medically needed technetium 99, of half-life T_1 = 6 hours, starting from its "parent" the molybdenum of half-life T_2 = 67 hours, allows a weekly supply.

1) Why is it preferable, in medical service that requires the use of technetium 99, to keep a reserve of molybdenum 99 and not a reserve of technetium 99 ?
2) Determine the number of technetium 99 nuclei obtained from a mass of 1g of molybdenum 99 at the end of 24 hours. Deduce the mass of these technetium nuclei.

Given : Masses of nuclei and particles: $^{99}_{42}Mo$ = 98,88437 u; $^{99}_{43}Tc$ = 98,88235 u; $^{0}_{-1}e = 55\times10^{-5}u$.

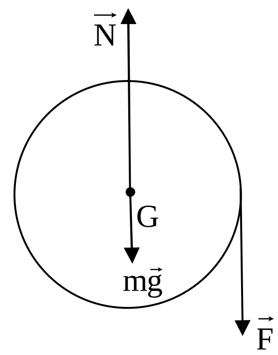
1u = 931,5 MeV/c^2 = 1,66 $\times10^{-27}$ kg ;

Planck's constant: h = 6,63 $\times10^{-34}$ J.s ;

1eV = 1,6 10^{-19}J ;

c = 3 $\times10^8$ m/s .

First exercise. (7pts)



A- 1) a – The weight $m\vec{g}$, the reaction $\vec{N}$ and the force $\vec{F}$ (½)

b- $\mathcal{M}(m\vec{g}) = \mathcal{M}(\vec{N}) = 0$ (on the axis)

$\mathcal{M}(\vec{F}) = M \Rightarrow \sum \mathcal{M} = M$ (½)

c- $\frac{d\sigma}{dt} = I_0\ddot{\theta} = M \Rightarrow \ddot{\theta} = \frac{M}{I_0}$ = cte and $\dot{\theta}_0 = 0 \Rightarrow$ Motion is uniformly accelerated. (¾)

2) a- $\frac{d\sigma}{dt} = M \Rightarrow \sigma = Mt + \sigma_0 \quad \sigma_0 = I_0\,\theta_0' = 0 \Rightarrow \sigma = Mt$ (¾)

b- $I_0\theta' = Mt \Rightarrow I_0 = \frac{Mt}{\theta'} = \frac{0,2 \times 5}{2 \times \pi \times 80} = 2 \times 10^{-3}\ Kgm^2$ (½)

B-1) M.E= $\frac{1}{2}I\theta'^2$ - mgR cosθ (**1**)

2) $\frac{dME}{dt} = 0 \Rightarrow I\,\theta'\theta'' + mg\,R\theta'\sin\theta = 0$ or $\sin\theta = \theta \Rightarrow \theta'' + mg\frac{R}{I}\theta = 0$ (**1**)

3) $\omega^2 = \frac{mgR}{I} \Rightarrow T = 2\pi\sqrt{\frac{I}{mgR}}$ (½)

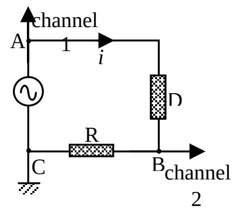
4) $T = \frac{7.7}{10} = 0.77$ s thus :

$I = \frac{T^2 mgR}{4\pi^2} = \frac{(0.77)^2 \times 0.4 \times 10 \times 0.1 \times (0.32)^2}{4} = 6.07 \times 10^{\ 3}\ kgm^2$ (**1**)

5) The relation $I = I_0 + mR^2$ gives $I_0 = 6 \times 10^{-3} - 0.4\,(0.1)^2 = 2 \times 10^{-3}\ kgm^2$. (½)

Second exercises (7 pts)

1) **connections** (½)



2) **a-** $\omega = 100\pi = \frac{2\pi}{T} \Rightarrow T = 2\times10^{-2}\,s = 20ms$ (½)

b- T corresponds to 4 div ; thus 4 div $\Rightarrow 2\times10^{-2}\,s \Rightarrow$
1 div. Corresponds to 5 ms => S_h = 5 ms/div (¾)

3) **a-** $i = \frac{u_{BC}}{R}$. Then i is the image of u_{BC} (½)

b- (D) is a capacitor since the current i leads the voltage u_{AC} (½)

4) **a-** $|\varphi| = \frac{2\pi\times0.5}{4} = \frac{\pi}{4}\text{rad}$; u_{BC} leads u_{AC} by $\frac{\pi}{4}\text{rad}$ (¾)

b- U_{mR} = 2 div × 2 V/div = 4 V ⇒ $I_m = \frac{U_{mR}}{R} = \frac{4}{40} = 0.1\text{A}$ (¾)

c- $i = 0{,}1\cos(100\pi t + \frac{\pi}{4})$ (½)

5) $i = C\frac{du_{AB}}{dt} \Rightarrow u_{AB} = \frac{1}{C}\int i\,dt = \frac{0{,}1}{100\pi C}\sin(100\pi t + \frac{\pi}{4})$ (**1**)

6) $u_{AC} = u_{AB} + u_{BC} \Rightarrow$

$4\sqrt{2}\cos(100\pi t) = \frac{0.1}{100\pi C}\sin(100\pi t + \frac{\pi}{4}) + 4\cos(100\pi t + \pi/4)$ (¼)

For $t = 0$: $4\sqrt{2} = \frac{0.1}{100\pi C}\frac{\sqrt{2}}{2} + 4\frac{\sqrt{2}}{2} \Rightarrow C = 80\mu F$ (**1**)

Third exercies (6 ½ pts)

A- 1) The two sources are synchronous ¼

2) The coherence ¼

3) since the sources are synchronous and coherent (or coherent) ¼

B-I – 1- a) Table ¾

λ (innm)	470	496	520	580	610
5 i (in mm)	11.75	12.40	13.00	14.50	15.25
i (in mm)	2,35	2,48	2,60	2.90	3.05

b) i- $\frac{i}{\lambda} = \frac{2.35\times 10^{6}}{470} = \frac{3.05\times 10^{6}}{610}$ = …………..= 5000 = positive constant ½

ii- $\frac{i}{\lambda}$ α = 5000 ¼

iii- i = $\frac{\lambda D}{a} \Rightarrow \frac{i}{\lambda} = \alpha = 5000$ ¾

2) The relation i = $\frac{\lambda D}{a}$ allows aus to write : $\frac{i_1}{i_2} = \frac{D_1}{D_2}$. Thus $\frac{2,48}{3.72} = \frac{D}{D+0.5} \Rightarrow$ D = 1 m **1**

3) b = 5000 = $\frac{D}{a} = \frac{1}{a}$ => a = 0.2 mm ½

II- 1) $\lambda_{air} = \frac{c}{f}$; $\lambda_{water} = \frac{V}{f}$ => $\frac{\lambda_{water}}{\lambda_{air}} = \frac{V}{c} = \frac{1}{n} \Rightarrow \lambda_{water} < \lambda_{air}$. ½

½

2) i is proprtional to λ ; upon passing from air to water, the wavelength decreases,this leads to a decrease in the interfringe distance i and the system of fringes seems closer

3) i_{water} = 1.95 mm ; $\frac{i_{water}}{i_{air}} = \frac{\lambda_{water}}{\lambda_{air}} = \frac{1}{n}$; thus $\frac{1.95}{2.6} = \frac{1}{n}$,

We get: n = 1.33 **1**

Fourth exercise (7 pts)

A- Conservation of mass number: 98 + A = 99 + 1 $\Rightarrow$ A = 2
Conservation of charge number: 42 + Z = 43 $\Rightarrow$ Z = 1. (½)

B- 1) $^{98}_{42}\text{Mo} \longrightarrow\ ^{99}_{43}\text{Tc} +\ ^{0}_{1}e +\ ^{0}_{0}\upsilon$ (½)

2) $\Delta m = m_{before} - m_{after} = 98.88437 - 98.88235 - 55\times10^{-5} = 1.47\times10^{-3}$ u (½)

$E = \Delta m\, c^2 = 1{,}47\times10^{-3}\times931.5\text{MeV}/c^2\times c^2 = 1.37$ MeV (¾)

3) a- i) $^{99}_{43}\text{Tc}^{*} \longrightarrow\ ^{99}_{43}\text{Tc} +$ (½)

ii) Electromagnetic (¼)

b- i) The conservation of total energy gives :

$m(^{99}_{43}\text{Tc}^{*})c^2 + E^{*}c = m(^{99}_{43}\text{Tc})\,c^2 + Ec + E(\gamma) \Rightarrow m(^{99}_{43}\text{Tc}^{*})c^2 = m(^{99}_{43}\text{Tc})\,c^2 + E(\gamma)$ (1½)

$\Rightarrow m(^{99}_{43}\text{Tc}^{*}) = m(^{99}_{43}\text{Tc}) + \dfrac{E(\gamma)}{c^2} = 98.88235\text{ u} + \dfrac{0.14\text{MeV}/c^2}{931.5}\text{ u} = 98.88250\text{ u}$

ii) $E_1 = \dfrac{hc}{\lambda} \Rightarrow \lambda = \dfrac{hc}{E_1} = \dfrac{6.63\times10^{-34}\times3\times10^{8}}{0.14\times1.60\times10^{\ 13}} = 8.88\times10^{-12}\text{ m}$ (½)

C- 1) The molybdenum 99 has a half-life 10 times longer than that of technetium99, it thus lasts stored for a longer time (½)

2) The number of nuclei of $^{99}_{42}\text{Mo}$ at the instant $t_0 = 0$ is :

$N_o = \dfrac{10^{24}}{1.66\times98.88437} = 6.09\times10^{21}$ nuclei (1/2) the number of $^{99}_{42}\text{Mo}$ nuclei at the instant t = 24 h is

$N = N_o e^{-\lambda t} = 6.09\times10^{21}\, e^{-\frac{0.693\times24}{67}} = 4.75\times10^{21}$nuclei (1/2)

The number of technetium nuclei obtained at the end of 24 hours is : $N_0 - N = 1.34\times10^{21}$ nuclei
The mass of Tc is : $1.34\times10^{21}\times98.88235\times1.66\ 10^{-27} = 0.22$ g
(1/2)