

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

***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 (7pts) Moment of inertia of a disk

Consider a homogeneous disk (D) of mass $m = 400 \text{ g}$ and of radius $R = 10 \text{ cm}$.

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: $0.32\pi = 1$; $g = 10 \text{ m/s}^2$; $\sin \theta = \theta$ (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 $M = 0.2m.N$. At the instant $t_1 = 5\text{s}$, (D) rotates then at the rotational speed $N_1 = 80 \text{ turns/s}$.

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 σ of the disk, about (Δ_0) , as a function of t .

b - Determine the value of I_0 .

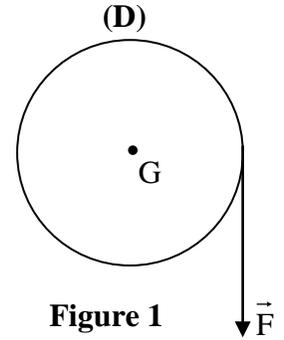


Figure 1

B – Second method

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

We denote by I the moment of inertia of (D) about (Δ) . 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 vertical 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 O is taken as a gravitational potential energy reference.

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) Knowing that I_0 and I are related by the relation $I = I_0 + mR^2$, find again the value of I_0 .

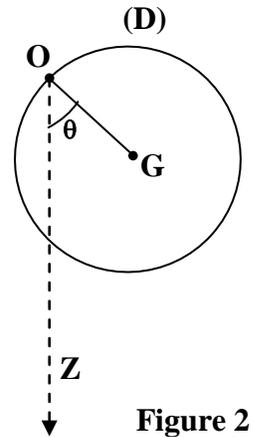


Figure 2

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 $R = 40 \Omega$ across a generator delivering across its terminals an alternating sinusoidal voltage:

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

The circuit thus carries an alternating sinusoidal current i .

An oscilloscope, conveniently connected, displays the waveforms that represent the variation, as a function of time, of the voltage $u_{AC} = u_g$ on channel 1 and that of the voltage $u_{BC} = u_R$ across the resistor on channel 2 (fig.2). The vertical sensitivity on channel 2 is 2V/div.

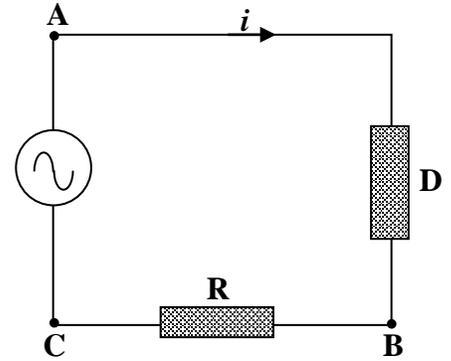
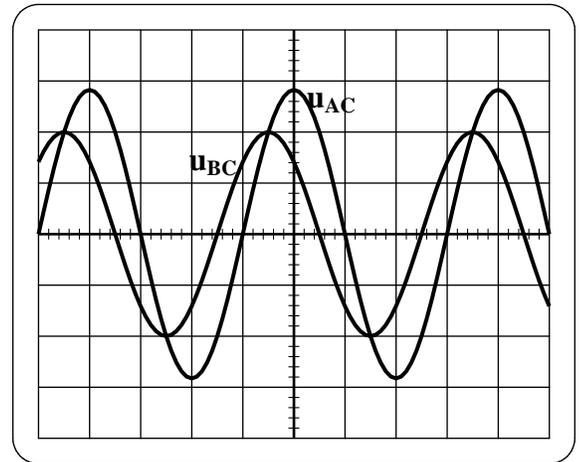


Figure 1

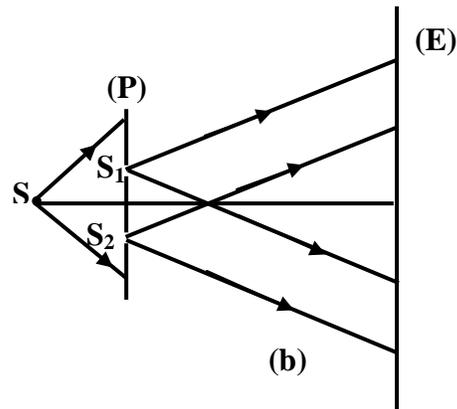
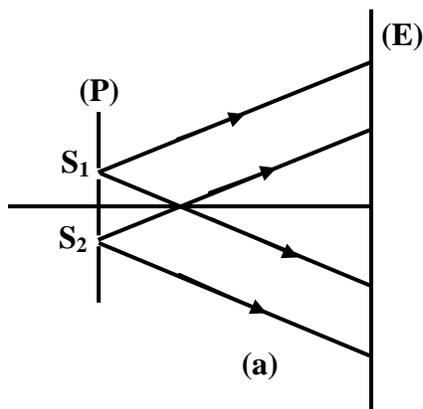
- 1) Redraw the figure 1 showing the connections of the oscilloscope.
- 2) a- Calculate the value of the period T of the voltage u_g .
b- Determine the horizontal sensitivity of the oscilloscope.
- 3) a- The waveform of u_{BC} represents the "image" of the current i . Why?
b- Specify the nature of the 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) a- 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 1/2 pts) Interference of light

A- Conditions to obtain a phenomenon of interference

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



In the set-up (a), each of the slits S_1 and S_2 is illuminated by a lamp; the two lamps emit the same radiation. In the set-up (b), S_1 and 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.

- 1- The radiations 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 and measurement

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 λ 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 (in nm)	470	496	520	580	610
$x = 5i$ (in mm)	11.75	12.40	13.00	14.50	15.25
i (in 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 $\lambda = 496$ 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

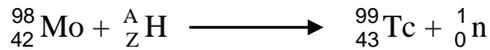
The radiation used now has a wavelength $\lambda = 520$ nm in air. The preceding apparatus is immersed completely in water whose index of refraction is n . The distance between the planes (E) and (P) is D and the distance between the slits is a .

- 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 .

Fourth exercise (7pts) The Technetium 99

A – A bit of history...

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



Determine Z and A specifying the laws used .

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

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

1) Write the equation corresponding to the decay of ${}^{99}_{42}\text{Mo}$.

2) Determine, in MeV, the energy liberated by this decay.

3) Most of the technetium nuclei obtained are in an excited state [${}^{99}_{43}\text{Tc}^*$]

a- i) Complete the equation of the following downward transition ${}^{99}_{43}\text{Tc}^* \longrightarrow {}^{99}_{43}\text{Tc} + \dots\dots$

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 [${}^{99}_{43}\text{Tc}^*$] and ${}^{99}_{43}\text{Tc}$ are supposed to be at rest.

i) Determine, in u, the mass of the ${}^{99}_{43}\text{Tc}^*$ nucleus.

ii) Calculate the wavelength of the emitted radiation.

C- Using technetium 99 in medicine

The isotope ${}^{99}_{43}\text{Tc}$ 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: ${}^{99}_{42}\text{Mo} = 98.88437$ u; ${}^{99}_{43}\text{Tc} = 98.88235$ u; ${}^0_{-1}e = 55 \times 10^{-5} u$.

$$1u = 931.5 \text{ MeV}/c^2 = 1.66 \times 10^{-27} \text{ kg} ;$$

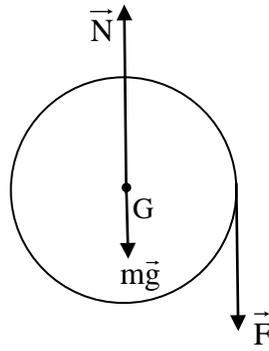
$$\text{Planck's constant: } h = 6.63 \times 10^{-34} \text{ J.s} ;$$

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

$$c = 3 \times 10^8 \text{ m/s} .$$

First exercise. (7pts)

1) a - The weight $m\vec{g}$, the reaction \vec{N} and the force \vec{F} (1/2)



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

$\mathcal{M}(\vec{F}) = M \Rightarrow \sum \mathcal{M} = M$ (1/2)

c- $\frac{d\sigma}{dt} = I_0\ddot{\theta} = M \Rightarrow \ddot{\theta} = \frac{M}{I_0} = \text{cte}$ and $\dot{\theta}_0 = 0 \Rightarrow$ Motion is uniformly accelerated. (3/4)

2) a- $\frac{d\sigma}{dt} = M \Rightarrow \sigma = Mt + \sigma_0$ $\sigma_0 = I_0\dot{\theta}_0 = 0 \Rightarrow \sigma = Mt$ (3/4)

b- $I_0\dot{\theta}' = Mt \Rightarrow I_0 = \frac{Mt}{\dot{\theta}'} = \frac{0,2 \times 5}{2 \times \pi \times 80} = 2 \times 10^{-3} \text{ Kgm}^2$ (1/2)

B- 1) M.E = $\frac{1}{2} I \dot{\theta}^2 - mgR \cos\theta$ (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) $\omega^2 = \frac{mgR}{I} \Rightarrow T = 2\pi \sqrt{\frac{I}{mgR}}$ (1/2)

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

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

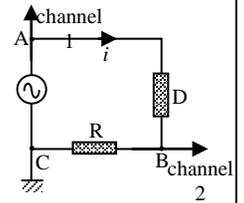
5) The relation $I = I_0 + mR^2$ gives $I_0 = 6 \times 10^{-3} - 0.4 (0.1)^2 = 2 \times 10^{-3} \text{ kgm}^2$ (1/2)

Secon exercies (7 pts)

1) connections (1/2)

2) a- $\omega = 100\pi = \frac{2\pi}{T} \Rightarrow T = 2 \times 10^{-2} \text{ s} = 20 \text{ ms}$ (1/2)

b- T corresponds to 4 div ; thus 4 div $\Rightarrow 2 \times 10^2 \text{ s} \Rightarrow$ 1 div. Corresponds to 5 ms $\Rightarrow S_h = 5 \text{ ms/div}$ (3/4)



3) a- $i = \frac{u_{BC}}{R}$. Then i is the image of u_{BC} (1/2)

b- (D) is a capacitor since the current i leads the voltage u_{AC} (1/2)

4) a- $|\varphi| = \frac{2\pi \times 0.5}{4} = \frac{\pi}{4} \text{ rad}$; u_{BC} leads u_{AC} by $\frac{\pi}{4} \text{ rad}$ (3/4)

b- $U_{mR} = 2 \text{ div} \times 2 \text{ V/div} = 4 \text{ V} \Rightarrow I_m = \frac{U_{mR}}{R} = \frac{4}{40} = 0.1 \text{ A}$ (3/4)

c- $i = 0,1 \cos(100\pi t + \frac{\pi}{4})$ (1/2)

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

$4\sqrt{2} \cos(100\pi t) = \frac{0.1}{100\pi C} \sin(100\pi t + \frac{\pi}{4}) + 4 \cos(100\pi t + \pi/4)$ (1/4)

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

Third exercises (6 1/2 pts)

A- 1) The two sources are synchronous

1/4

2) The coherence

1/4

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

1/4

B-I- 1- a) Table

3/4

λ (innm)	470	496	520	580	610
5 i	11.75	12.40	13.00	14.50	15.25
(in mm)					
i (in mm)	2,35	2,48	2,60	2,90	3,05

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

1/2

ii- $\frac{i}{\lambda} \alpha = 5000$

1/4

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

3/4

2) The relation $i = \frac{\lambda D}{a}$ allows us to write : $\frac{i_1}{i_2} = \frac{D_1}{D_2}$. Thus $\frac{2,48}{3,72} = \frac{D}{D + 0,5} \Rightarrow D = 1$

1

3) $b = 5000 = \frac{D}{a} = \frac{1}{a} \Rightarrow a = 0,2 \text{ mm}$

1/2

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

1/2

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

1/2

3) $i_{water} = 1,95 \text{ mm}$; $\frac{i_{water}}{i_{air}} = \frac{\lambda_{water}}{\lambda_{air}} = \frac{1}{n}$; thus $\frac{1,95}{2,6} = \frac{1}{n}$,

We get: $n = 1,33$

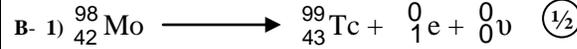
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Fourth exercise (7 pts)

A- Conservation of mass number: $98 + A = 99 + 1 \Rightarrow A = 2$

Conservation of charge number: $42 + Z = 43 \Rightarrow Z = 1$

1/2



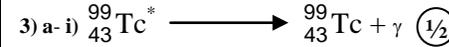
1/2

2) $\Delta m = m_{\text{before}} - m_{\text{after}} = 98.88437 - 98.88235 - 55 \times 10^{-5} = 1,47 \times 10^{-3} \text{ u}$

1/2

$E = \Delta m c^2 = 1,47 \times 10^{-3} \times 931,5 \text{ MeV}/c^2 \times c^2 = 1,37 \text{ MeV}$

3/4



1/2

ii) Electromagnetic

1/4

b- i) The conservation of total energy gives :

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

1/2

$\Rightarrow m({}_{43}^{99}\text{Tc}^*) = m({}_{43}^{99}\text{Tc}) + \frac{E(\gamma)}{c^2} = 98,88235 \text{ u} + \frac{0,14 \text{ MeV}/c^2}{931,5} \text{ u} = 98,88250 \text{ u}$

ii) $E_1 = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E_1} = \frac{6,63 \times 10^{-34} \times 3 \times 10^8}{0,14 \times 1,60 \times 10^{13}} = 8,88 \times 10^{-12} \text{ m}$

1/2

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

1/2

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

$N_0 = \frac{10^{24}}{1,66 \times 98,88437} = 6,09 \times 10^{21} \text{ nuclei}$ the number of ${}_{42}^{99}\text{Mo}$ nuclei at the instant $t = 24 \text{ h}$ is

1/2

$N = N_0 e^{-\lambda t} = 6,09 \times 10^{21} e^{-\frac{0,693 \times 24}{67}} = 4,75 \times 10^{21} \text{ nuclei}$

1/2

The number of technetium nuclei obtained at the end of 24 hours is : $N_0 - N = 1,34 \times 10^{21}$ nuclei
The mass of Tc is : $1,34 \times 10^{21} \times 98,88235 \times 1,66 \times 10^{-27} = 0,22 \text{ g}$

1/2