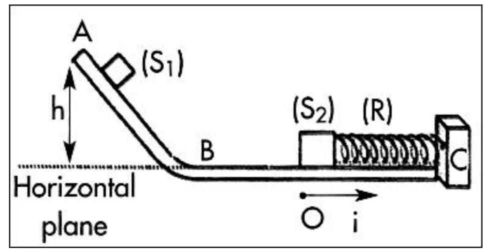
دورة سنة 2003 العادية	امتحانات شهادة الثانوية العامة فرع العلوم العامة	وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات
الاسم : الرقم :	مسابقة في الفيزياء المدة : ثلاث ساعات	

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

<u>First Exercise</u> (6 ½ points) Determination of the force constant of a spring

In order to determine the force constant k of a spring (R) of un-jointed turns, we consider:

- a frictionless track ABC found in a vertical plane,
- a spring (R) having one end fixed to a support C and its other end connected to a solid (S_2) of mass m_2 of negligible dimensions.
- a solid (S_1) of mass $m_1 = 0.1$ kg and of negligible dimensions held at A at height h = 0.8 m above the horizontal plane containing BC.



The horizontal plane containing BC is taken as the gravitational potential energy reference. Take g = 10 m/s^2.

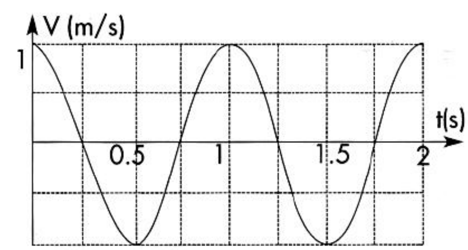
1- (S_1), released from rest at A, reaches (S_2) with a velocity $\vec{V}_1$. Show that the magnitude of $\vec{V}_1$ is $V_1 = 4$ m/s.

2- (S_1), collides with (S_2) and sticks to it, thus forming a particle (S). Determine, in terms of m_2, the expression of V_o the magnitude of the velocity $\vec{V}_o$ of (S) just after the impact.

3- The system [(S), (R)] forms a horizontal elastic pendulum, (S) oscillating around its equilibrium position at O.

a- Determine the differential equation that describes the motion of the oscillator. Deduce the expression of its proper period T_o.

b- Figure (2) represents the variation of the algebraic value of the velocity of (S) as a function of time.
The origin of time corresponds to the instant when the velocity of (S) is $\vec{V}_o$.



i- Give the value V_o of $\vec{V}_o$.
ii- Deduce the value of m_2.
iii- Give the value of T_o.
iv- Calculate k.

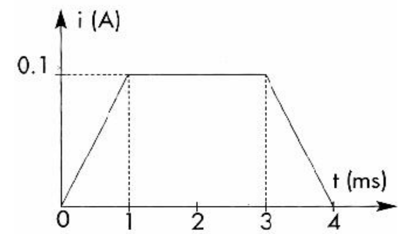
Second Exercise (7 points) Role and characteristics of a coil

Consider a coil (B) that bears the following indications: L = 65 mH and r = 20 Ω.

A- Role of a coil

In order to show the role of a coil, we connect the coil across a generator G_1 .

The variation of the current i carried by the coil as a function of time is represented in figure (1).



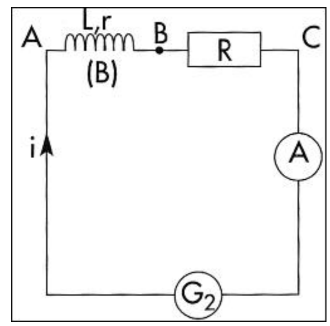
1- a- Give, in terms of L and i, the literal expression of the induced electromotive force e produced across the coil.

b- Determine the value of e in each of the following time intervals: [0; 1ms], [1 ms; 3 ms], [3 ms; 4 ms].

2- In what time interval would the coil act as a generator? Justify your answer.

B- Characteristics of the coil

In order to verify the values of L and r, we perform the two following experiments:

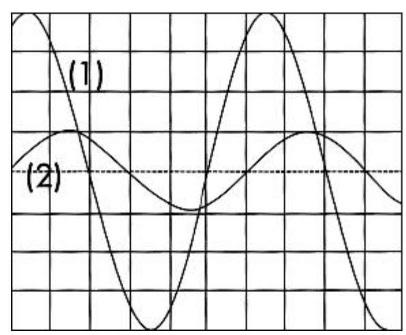


I- **First experiment:** The coil (B), a resistor of resistance R = 20 Ω and an ammeter of negligible resistance are connected in series across a generator (G_2) of electromotive force E = 4 V and of negligible internal resistance (figure 2). After a certain time, the ammeter reads I = 0.1 A. Deduce the value of r.

II- **Second experiment:** The ammeter is removed and G_2 is replaced by a generator G_3 delivering an alternating sinusoidal voltage.

1- Redraw figure (2) and show on it the connections of an oscilloscope that allows to display, on the channel (1), the voltage v_g across the generator and, on channel (2), the voltage v_R across the resistor.

2- The voltages displayed on the oscilloscope are represented on figure (3).



Given: vertical sensitivity on both channels: 2 V/division.
horizontal sensitivity: 1 ms/division.

a- The waveform (1) represents v_g. Why?

b- The voltage across the generator has the form: $v_g = V_m\cos\omega t$. Determine U_m and ω.

c- Determine the phase difference φ between v_g and v_R.

d- Determine the expression of the instantaneous current i carried by the circuit.

e- Using the law of addition of voltages at an instant t, and using a particular value of t, deduce the value of the inductance L.

III- Compare the values found for r and L, with those indicated on the coil.

Third exercise (6 ½ points) The two aspects of light

To show evidence of the two aspects of light, we perform the two following experiments:

A- First experiment

We cover a metallic plate by a thin layer of cesium whose threshold wavelength is $\lambda_o = 670$ nm. Then we illuminate it with a monochromatic radiation of wavelength in vacuum $\lambda = 480$ nm. A convenient apparatus is placed near the plate in order to detect the electrons emitted by the illuminated plate.

1- This emission of electrons by the plate shows evidence of an effect. What is that effect?

2- What does the term "threshold wavelength" represent?

3- Calculate, in J and eV, the extraction energy (work function) of the cesium layer.

4- What is the form of energy carried by an electron emitted by the plate? Give the maximum value of this energy.

Given: Planck's constant: $h = 6.6 \times 10^{-34}$ J.s;
speed of light in vacuum: $c = 3 \times 10^{8}$ m/s;
1 eV= 1.6×10^{-19} J.

B- Second experiment

The two thin slits of Young's apparatus, separated by a distance a, are illuminated with a laser light whose wavelength in vacuum is $\lambda = 480$ nm. The distance between the screen of observation and the plane of the slits is D=2m.

1- Draw a diagram of the apparatus and show on it the region of the interference.

2- The conditions to obtain the phenomenon of interference on the screen are satisfied. Why?

3- Due to what is the phenomenon of interference?

4- **a-** Describe the aspect of the region of interference observed on the screen.

b- We count 11 bright fringes. The distance between the centers of the farthest fringes is l = 9.5 mm. What do we call the distance between the centers of two consecutive bright fringes? Calculate its value and deduce the value of a.

C- The two experiments show evidence of two aspects of light. Specify the aspect shown by each experiment.

<u>Fourth exercise</u> (7½points) Radioactivity of polonium 210

In order to study the radioactivity of polonium $^{210}_{84}Po$ which is an α emitter, we take a sample of polonium 210 containing N_o nuclei at the instant $t_o = 0$.

A- Determination of the half-life (period)

We measure, at successive instants, the number N of the remaining nuclei. We calculate the ratio N/N_o and the result is tabulated as in the following table:

t (in days)	0	50	100	150	200	250	300
N / N_o	1	0.78	0.61	0.47	0.37	0.29	0.22
$-\ln (N / N_o)$	0	0.25				1.24	

1- Draw again the above table and complete it by calculating at each instant $- \ln (N/N_o)$.

2- Trace the curve representing the variation of $f(t) = - \ln (N/N_o)$, as a function of time, using the scale: 1 cm on the abscissa represents 25 days; 1 cm on the ordinate represents 0.1.

3- a- Knowing that $Ln(N/N_o) = -\lambda t$, determine graphically the value of the radioactive constant λ of polonium 210.

b- Deduce the half-life of polonium 210.

B- Activity of polonium 210

1- Define the activity of a radioactive sample.

2- Give the expression of the activity A_o of the sample at the instant $t_o = 0$, in terms of λ and N_o. Calculate its value for $N_o = 5 \times 10^{18}$.

3- Give the expression, in terms of t, of the activity A of the sample.

4- Calculate the activity A:

a- at the instant t = 90 days.

b- When t increases indefinitely.

C- Energy liberated by the disintegration of polonium 210

1- The disintegration of a nucleus of polonium produces a daughter nucleus which is an isotope of lead $^{A}_{Z}Pb$. Determine A and Z.

2- Calculate, in MeV, the energy liberated by the disintegration of one nucleus of polonium 210.

3- The disintegration of a polonium nucleus may take place with or without the emission of a photon. The energy of an emitted photon is 2.20 MeV. Knowing that the daughter nucleus has a negligible velocity, determine in each case the kinetic energy of the emitted α particle.

4- The sample is put in an aluminum container. Thus, the α particles are stopped by the container whereas the photons are not.
Knowing that half of the disintegrations are accompanied by a γ emission, determine the power transferred to the aluminum container at the instant t = 90 days.

Numerical data:

Mass of a polonium 210 nucleus: 209.9828 u

Mass of lead (Pb) nucleus: 205.9745 u

Mass of an α particle: 4.0015 u

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

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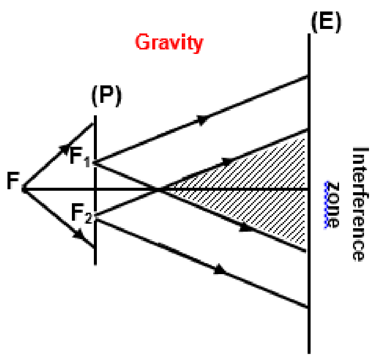
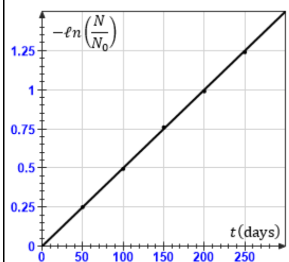
Question I (6.5 points)		
1.	Friction being negligible, the mechanical energy of the system [(S_1), Earth] is conserved: $KE_A + GPE_A = KE_O + GPE_O$. Thus, $v_1 = \sqrt{2gh} = \sqrt{2 \times 10 \times 0.8} = 4m/s$	**1**
2.	The linear momentum of the system [$(S_1), (S_2)$] is conserved: $\overrightarrow{v_0} = \frac{m_1}{m_1 + m_2}\overrightarrow{v_1}$ $\overrightarrow{v_0} = \frac{0.4\vec{i}}{0.1 + m_2}$ where m_2 in kg & v_0 in m/s	**0.5** **0.5**
3.a)	$ME = \frac{1}{2}(m_1 + m_2)v^2 + \frac{1}{2}kx^2$ This mechanical energy is conserved because the forces of friction are negligible: $\frac{d(ME)}{dt} = 0$; we get: $x'' + \frac{k}{m_1 + m_2}x = 0$	**0.25** **0.25** **0.5**
3.b)	The differential equation that governs the motion of the solid (S) is of the form $x'' + \omega_0^2 x = 0; \omega_0 = \sqrt{\frac{k}{m_1+m_2}}$ $T_0 = \frac{2\pi}{\omega_0} = 2\pi\sqrt{\frac{m_1+m_2}{k}}$	**0.5** **0.5** **0.5**
4.a)	$v_0 = 1m/s$	**0.5**
4.b)	$v_0 = \frac{0.4}{0.1 + m_2} = 1$, then $m_2 = 0.4kg - 0.1kg = 0.3kg$.	**0.5**
4.c)	$T_0 = 1s$.	**0.25**
4.d)	$T_0 = 2\pi\sqrt{\frac{m_1 + m_2}{k}}$; Then $k = \frac{4\pi^2(m_1 + m_2)}{T_0^2} = 16N/m$	**0.75**

Question II (07 points)		
A-1.a)	$e = -L\frac{di}{dt}$	**0.25**
A-1.b)	For $t \in [0; 1ms]$, the current varies linearly; then: $\frac{di}{dt} = \frac{\Delta i}{\Delta t} = \frac{(0.1-0)A}{(1-0)\times 10^{-3}s} = +100A/s$; So, $e = -65\times 10^{-3}\times 100 = -6.5V$ For $t \in [1ms; 3ms]$, $e = 0V$; For $t \in [3ms; 4ms]$, So, $e = -65\times 10^{-3}\times(-100) = +6.5V$	**0.75** **0.25** **0.5**
A-2.	If $t \in [3ms; 4ms]$, the coil acts as a generator since $e = 6.5V > 0$	**0.5**
B-I-1.	$E = rI + RI$; $4 = r\times 0.1 + 20\times 0.1$ thus $r = \left(\frac{4-2}{0.1}\right) = 20\Omega$	**0.5**
B-II-1.	Diagram	**0.5**
B-II-2.a)	Due to the inductive effect of the coil present in the circuit, the voltage across the generator u_G should lead the current whose image is u_R.	**0.5**
B-II-2.b)	$U_m = S_{v_1}\times y_{1(\max)} = 8V$. The period: $T = S_h \times x = 6ms$; $\omega = \frac{2\pi}{T} = \frac{1000\,\pi}{3}(\text{rad}/s)$;	**0.5** **0.25** **0.5**
B-II-2.c)	$\lvert\varphi\rvert = 2\pi\times\frac{d}{D} = \frac{\pi}{3}(\text{rad})$ Then $u_R = 2\cos\left(\frac{1000\,\pi t}{3} - \frac{\pi}{3}\right)$ Ohm's law: $i = 0.1\cos\left(\frac{1000\,\pi t}{3} - \frac{\pi}{3}\right)$ (t in s and i in A)	**0.25** **0.25** **0.5**
B-II-2.d)	Law of addition of voltages: $u_G = u_{AB} + u_{BC}$; Let $\frac{1000\,\pi t}{3} = 0$, We get $L = \frac{6\times 6}{100\pi\sqrt{3}} \approx 0.066H = 66mH$	**1**

Question III (6.5 points)		
A-1.	The photoelectric effect shows an evidence of corpuscular aspect of light.	**0.25**
A-2.	Definition	**0.5**
A-3.	$W_0 = \frac{hc}{\lambda_0} = 2.96 \times 10^{-19} J = 1.85\ eV$	**0.75**
A-4.	The electron emitted carries kinetic energy. $\lambda < \lambda_0 = 670 nm$, electrons are ejected from the surface of the metal; According to Einstein's relation: $E_{ph} = W_0 + KE_{\max}$. $KE_{\max} = 1.2 \times 10^{-19} J$	**0.25** **0.75**
B-1.	Diagram 	**0.5**
B-2.	Same primary source, then coherent sources.	**0.5**
B-3.	The interference phenomenon is due to the superposition of two synchronous and coherent beams	**0.5**
B-4.a)	On the screen, in the interference zone, we observe: - a central bright fringe. - alternate, equidistant straight bright and dark fringes.	**0.5**
B.4.b)	The distance between the centers of two consecutives bright fringes is called interfringe distance. $i = 0.95 mm$. We have $a = \frac{\lambda D}{i} = 1 mm$	**0.5** **0.25** **0.75**
C	The first experiment (photoelectric emission) shows evidence of the corpuscular aspect of light while the second experiment (interference) shows the wave aspect of light	**0.5**

Question IV (7.5 points)		
A-1.	0 - 0.25 - 0.49 - 0.76 - 0.99 - 1.24 - 1.51	**0.5**
A-2.		**0.75**
A-3.a)	$\lambda = \dfrac{0.25 - 0}{(50 - 0)\text{days}} = 5 \times 10^{-3}\text{day}^{-1}$.	**0.5**
A-3.b)	The period of polonium is: $T = \dfrac{\ell n2}{\lambda} = \dfrac{\ell n2}{5 \times 10^{-3}} = 139$ days.	**0.75**
B-1.	The activity of a radioactive sample is the number of disintegrations per unit of time.	**0.5**
B-2.	$A_0 = 5 \times 10^{-3} \times 5 \times 10^{18} = 2.5 \times 10^{16}$decays per day	**0.5**
B-3.	$A = A_0 e^{-\lambda t}$.	**0.25**
B-4.a)	At $t = 90$ days: $A = 2.5 \times 10^{16}(\text{decays/day})e^{-4.9 \times 10^{-3}\text{day}^{-1} \times 90\text{ days}}$ $= 1.59 \times 10^{16}(\text{decays/day})$	**0.5**
B-3.b)	As $t \to +\infty$, $e^{-\lambda t} \to 0$; then $A \to 0$ (practically all the nuclei are disintegrated).	**0.25**
C-1.	Conservation of mass number: $210 = 4 + A$, then $A = 206$; Conservation of charge number: $84 = 2 + Z$, then $Z = 82$	**0.5**
C-2.	The mass defect $\Delta m = 209.9828u - (205.9745u + 4.0015u) = 6.8 \times 10^{-3}u$; The energy liberated is: $E_\ell = 6.33 MeV$.	**0.5** **0.25**
C-4.	Without the emission of γ-radiation $KE_{\alpha_1} = E_\ell = 6.33\ MeV$; With the emission of γ-radiation $KE_{\alpha_2} = E_\ell - E_\gamma = 4.13 MeV$.	**0.25** **0.25**
C-3.	After 90days, the activity becomes 1.59×10^{16}decays per day. So, $A = 1.83 \times 10^{11} Bq$; The power absorbed is $P_{ab} = \dfrac{N_d \times KE_\alpha}{\Delta t} = A \times KE_\alpha$; But we have two equal amounts of disintegrations α_1 of α_2, then: $P_{ab} = \dfrac{A}{2}(KE_{\alpha_1} + KE_{\alpha_2})$; Thus, $P_{ab} = \dfrac{1.83 \times 10^{11}}{2}(6.33 + 4.13) \times 1.6 \times 10^{-13} = 0.153W$.	**0.25** **0.5** **0.5**