امتحانات شهادة الثانوية العامة
فرع العلوم العامة

دورة سنة ٢٠٠٥ العادية

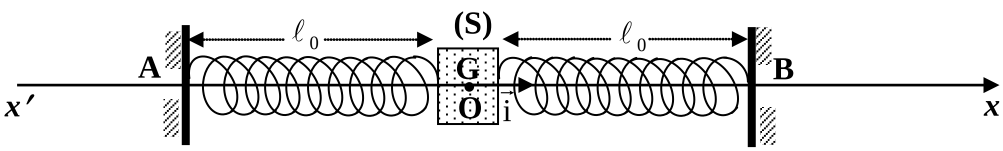
مسابقة في الفيزياء
المدة: ثلاث ساعات

الاسم :
الرقم :

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

First Exercise: (7 pts) Study of a horizontal mechanical oscillator

A solid (S), of mass m = 140 g, may slide on a straight horizontal track. The solid is connected to two identical springs of un-jointed turns, of negligible mass, fixed between two supports A and B.
Each of these springs has a stiffness (force constant) k = 0.60 N/m, and a free length ℓ_0 .
We denote by O the position of the center of mass G of (S) when the oscillator [(S) + two springs] is in equilibrium, each spring having then the length ℓ_0 (figure).



The solid is shifted from this equilibrium position along the direction *x' x*, by a distance of 4.2 cm, and then released without initial velocity at the instant $t_o = 0$. During its oscillations, at any instant t, the abscissa of G is x and the algebraic value of its velocity is V, O being the origin of abscissas.
The horizontal plane through G is taken as a gravitational potential energy reference.

I – Theoretical study

In this part, we neglect friction.
The solid (S) performs ,in this case, oscillations of amplitude X_{mo} = 4.2 cm.

1) a) Show that the expression of the elastic potential energy of the oscillator is $P.E_e = kx^2$.
b) Write the expression of the mechanical energy M.E of the system [oscillator, Earth] as a function of m, V, x and k.

2)a) Derive the differential equation that governs the motion of (S).
b) Deduce the expression of the proper period T_o of the oscillator in terms of m and k.
c) Calculate the value of T_o. Take $\pi = 3.14$

II – Experimental study

In reality, the value of the amplitude X_m decreases during oscillations, each of duration T.
Some values of X_m are tabulated as below.

Instant	0	T	2T	3T	4T	5T
Amplitude X_m(cm)	X_{mo}= 4.20	X_{m1}= 2.86	X_{m2} =1.95	X_{m3} = 1.33	X_{m4} = 0.91	X_{m5} = 0.62

1) Draw the shape of the curve representing the variation of the abscissa x of G as a function of time.

Scale: on the axis of abscissas 1cm represents $\frac{T}{2}$ and on the axis of ordinates 1 cm represents 1cm.

2) The duration of 5 oscillations is measured and found to be 10.75 s.

- **a)** Calculate T.
- **b)** Compare T and T_o.
- **c)** What is then the type of oscillations?

3) The decrease in the mechanical energy of the system [oscillator, Earth] is due to the existence of a force of friction of the form $\vec{f} = -h\vec{V}$ where $\vec{V} = V\vec{i}$ and h is a positive constant.

a) From the above table of values, verify that:

$$\frac{X_{m1}}{X_{mo}} \approx \frac{X_{m2}}{X_{m1}} \approx \ldots\ldots \approx A \quad \text{where A is a positive constant.}$$

b) Knowing that A is given by the expression $A = e^{\frac{-hT}{2m}}$, calculate h.

4) In order to compensate for the loss in the mechanical energy of the system, an apparatus (D) allows, at regular time intervals, to provide energy to the oscillator.

- **a)** Determine the average power furnished by (D) between the instants t = 0 and t = 5 T.
- **b)** What is then the type of oscillations?

Second Exercise: (7 ½ pts) Flash of a camera

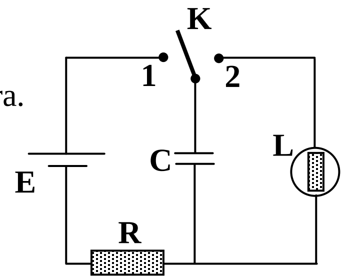


Figure 1

In this exercise, we intend to show evidence of the functioning of the flash of a camera. The simplified circuit of the flash of a camera is formed of an apparatus taken as a source of DC voltage of E = 300 V, a capacitor of capacitance C = 200 μF, a resistor of resistance R = 10 kΩ, a lamp (L), considered as a resistor of resistance r = 1 Ω and a double switch K (figure 1).

I – Charging the capacitor

The capacitor is initially neutral. The double switch is turned to position 1 at the instant $t_o = 0$. The capacitor starts charging (figure 2)

1) a) Derive , at an instant t ,the differential equation that governs the variation of the voltage $u_c = u_{MN}$,as a function of time ,during the charging of the capacitor.

b) The solution of this equation, at an instant t, has the form: $u_c = A + B\,e^{\frac{-t}{\tau}}$ where A, B and τ are constants. Determine these constants in terms of E, R and C.

2) Calculate the energy W stored by the capacitor at the end of charging.

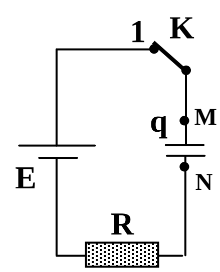


Figure 2

II- Discharging the capacitor

The capacitor being completely charged, the double switch is turned to position 2.

The capacitor starts to discharge through the lamp (L).

The instant of closing the circuit is taken as an origin of time. At an instant t, the voltage across the capacitor is $u_c = u_{MN} = E\,e^{\frac{-t}{rC}}$ and the circuit carries then a current i (figure 3) .

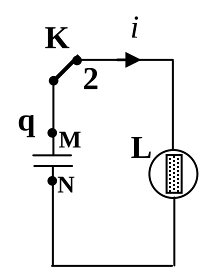


Figure 3

1. Justify the direction of the current in figure (3).

2. Knowing that $i = -\frac{dq}{dt}$

a) determine the expression of the current i as a function of time,
b) calculate the maximum value of i,
c) determine the duration t_1 at the end of which the current reaches 70 % of its maximum value.
d) calculate, at the instant t_1, the voltage u_C across the capacitor.

3. a) Assuming that the energy released by the capacitor by the end of the duration t_1 is converted totally into light in the lamp, determine the average power received by the lamp during t_1.

b) The flash lamp emits light as long as the average power it receives is greater or equal to 6.4×10^4 W.

Knowing that the duration of the flash is t_1, justify the emission of the flash between the instants 0 and t_1.

Third exercise : (7 pts) Photoelectric Effect

The experiments on photoelectric emission performed by Millikan around the year 1915, intended to determine the kinetic energy K.E of the electrons emitted by metallic cylinders of potassium (K) and cesium (Cs) when these cylinders are illuminated by monochromatic radiation of adjustable frequency ν.
The object of this exercise is to determine, performing similar experiments, Planck's constant (*h*), as well as the threshold frequency ν_o of potassium and the extraction energy W_o of potassium and that of cesium.

I - ***1)*** What aspect of light does the phenomenon of photoelectric effect show evidence of ?
2) A monochromatic radiation is formed of photons. Give two characteristics of a photon.
3) For a given pure metal, the incident photons of a monochromatic radiation provoke photoelectric emission. Give the condition for this emission to take place.

II- In a first experiment using potassium, a convenient apparatus is used to measure the kinetic energy K.E of the electrons corresponding to frequency ν of the incident radiation. The obtained results are tabulated in the following table:

ν (Hz)	K.E (eV)
6×10^{14}	0.25
7×10^{14}	0.65
8×10^{14}	1.05
9×10^{14}	1.45
10×10^{14}	1.85

Given : $1eV = 1.60 \times 10^{-19}J$.

1- Using Einstein's relation about photoelectric effect , show that the kinetic energy of an extracted electron may be written in the form : $K.E = a\nu + b$.

2- ***a)*** Plot , on the graph paper, the curve representing the variation of the kinetic energy K.E versus ν , using the following scale:

- on the axis of abscissas: 1cm represents a frequency of 10^{14}Hz
- on the axis of ordinates: 1 cm represents a kinetic energy of 0.5 eV.

b) Using the graph, determine:
i) the value, in SI, of h , the Planck's constant.
ii) the threshold frequency ν_o of potassium.

3- Deduce the value of the extraction energy W_o of potassium.

III- In a second experiment using cesium, we obtain the following values: K.E = 1 eV for $\nu = 7 \times 10^{14}$Hz.
1) Plot, with justification ,on the preceding system of axes, the graph of the variation of K.E as a function of ν.
2) Deduce from this graph the extraction energy W'_o of cesium.

Fourth exercise : (6 pts) Fuel and a power plant

The object of this exercise is to compare the masses of different fuels used in power plants producing the same electric power.
The power plant, of electric power $P = 3 \times 10^9$ W, has an efficiency supposed to be 30 % whatever the nature of the fuel used be.

A. Energy furnished by the fuel

Calculate, in J, the energy furnished by the fuel during 1 day.

B. I. Thermal power plant

The power plant uses fuel-oil. The combustion of 1kg of this fuel-oil liberates 4.5×10^7 J of energy.

Calculate, in kg, the mass m_1 of fuel-oil consumed during 1 day.

II. Power plant using nuclear fission

In the power plant , we use uranium enriched with ^{235}U. One of the fission reactions is :

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{94}_{38}Sr + ^{140}_{54}Xe + 2\ ^{1}_{0}n$$

1) In order that fission reaction may take place, the neutron used must satisfy a condition. What is it?
2) The fission of uranium 235 nucleus liberates energy of 189 MeV.
   a) In what form does this energy appear?
   b) Calculate , in kg, the mass m_2 of uranium 235 necessary for the power plant to function during 1 day.

III. Power plant using nuclear fusion?

The thermonuclear fusion reaction has not yet been controlled. If such controlling becomes within reach , we may provoke reactions like those taking place in the Sun.
The balanced fusion reaction of hydrogen in the Sun may be written as :

$$4\ ^{1}_{1}H \rightarrow ^{4}_{2}He + 2\ ^{A}_{Z}X$$

1) Identify the particle $^{A}_{Z}X$ specifying the laws used.
2) What condition must be satisfied for this fusion to take place?
3) Determine, in J, the energy liberated in the formation of a helium nucleus.
4) Calculate, in kg, the mass m_3 of hydrogen necessary for the power plant to function 1 day.

C. Suggest the mode that is the most convenient for the production of electric energy for a country .
Justify your answer.

Given :
1 u = 931.5 MeV/c^2 = 1.66 × 10^{-27} kg ; 1 MeV = 1.6 × 10^{-13}J ;
Masses of nuclei and particles $^{1}_{1}H$: 1.00728 u ; $^{4}_{2}He$: 4.00150 u ; $^{A}_{Z}X$: 0.00055 u ; ^{235}U : 235.04392 u.

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I-1-a) Epe= $1/2kx^2 + 1/2kx^2 = kx^2$ **(1/2pt)**

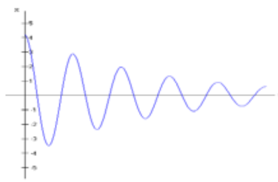
b) $E_m = E_C + Epe = ½\, m V^2 + kx^2$ **(1/2pt)**

2- a) E_m= cte => $\frac{dE_m}{dt} = 0 = m V \ddot{x} + 2kx V$ => $\ddot{x} + \frac{2k}{m} x = 0$ **(1/2pt)**

b) L'équation différentielle est de la forme $\ddot{x} + \omega_o^2 x = 0$ où $\omega_o = \sqrt{\frac{2k}{m}}$ est la pulsation propre du mouvement. La période propre est $T_o = \frac{2\pi}{\omega_o} = 2\pi\sqrt{\frac{m}{2k}}$. **(1pt)**

c) $T_o = 2\pi\sqrt{\frac{0,14}{2 \times 0,6}}$ = 2,145 s. **(1/2pt)**

II- 1) Allure de la courbe **(1/2pt)**



2) a) $T = \frac{10,75}{5} = 2,150$ s **(1/2pt)**

b) T= 2,150 s et T_o= 2,145s => $T > T_o$ **(1/4pt**

c) Oscillations libres amorties **(1/4pt)**

3) a) $A = \frac{2,86}{4,2}$ = 0,68 **(1/2pt)**

b) $\ln A = -\frac{h}{2m} T$. **(1/2pt)** D'où : h = 0,05 Kg/s **(1/2pt)**

4- a) $E_m = ½\, m V^2 + kx^2$. A chaque extremum, $V = 0$, donc $E_m = k(X_m)^2$

A t = 0 , $E_{m0} = k(X_{m0})^2 = 1,0584.10^{-3}$J.

A t = 5T , $E_{m5} = k(X_{m5})^2 = 0,0231.10^{-3}$J.

La diminution en énergie mécanique du système est $|\Delta E_m| = 1,0584.10^{-3} - 0,0231.10^{-3} = 1,0353.10^{-3}$ J.

D'où : $P_m = \frac{|\Delta E_m|}{5T} = \frac{1,0353 \times 10^{-3}}{5 \times 2,15} = 0,096.10^{-3}$W. **(1 1/4 pt)**

b) L'oscillateur effectue des oscillations entretenues. **(1/4 pt)**

I- 1- a) $E = Ri + u_C$, avec $i = dq/dt = Cdu_C/dt$; on a : $E = R\,Cdu_C/dt + u_C$. **(1 pt)**

b- $u_C = A + B\, e^{-\frac{t}{\tau}}$; $du_C/dt = -\frac{B}{\tau} e^{-\frac{t}{\tau}}$ => $E = -RC\frac{B}{\tau} e^{-\frac{t}{\tau}} + A + B\, e^{-\frac{t}{\tau}}$ =>

$B\, e^{-\frac{t}{\tau}} (1-\frac{RC}{\tau}) + (A- E) = 0$ $\forall$ t => $(1-\frac{RC}{\tau}) = 0$ => τ **= RC** et A – E = 0 => .

A= E . D'autre part à t = 0 , $u_{C=}$ 0 => A + B = 0 => **B = - E** **(11/2pt)**

2- W= ½ C $(u_C)^2$ = ½ CE^2 => W = 9 J **(1/2pt)**

II- 1) $u_{MN} > 0$ => le courant passe dans le sens du potentiel décroissant.**(1/2 pt)**

2) a) $i = -\frac{dq}{dt} = -C\frac{du_C}{dt} = C\frac{E}{rC} e^{\frac{-t}{rC}} = \frac{E}{r} e^{\frac{-t}{rC}}$ **(1/2pt)**

b) $I_{max} = \frac{E}{r}$ = 300 A. **(1/2pt)**

c) Au bout d'une durée t_1, on a : i = 0,7 I_{max} = 0,7 $\frac{E}{r}$ => $\frac{E}{r} e^{-\frac{t_1}{rC}} = 0,7\frac{E}{r}$

=> $e^{-\frac{t_1}{rC}} = 0,7$ ou $\frac{t_1}{rC} = 0,356$ => $t_1 = 7.10^{-5}$s **(1pt)**

d) si $t = t_1 = 7.10^{-5}$s , la tension aux bornes du condensateur est :

$u_C = E\, e^{-\frac{t_1}{rC}} = 300 \times e^{-0,35} = 211,41$ V . **(1 pt)**

3-a) L'énergie du condensateur à l'instant t_1 est donc : W_1 = ½ C $(u_C)^2$ = $10^{-4}(211,41)^2$ = 4,5 J.

$\Delta W = W – W_1$ = 4,5 J **(1/2pt)**

$P_m = \frac{\Delta W}{t_1} = 6,4.10^4$ W.

b)) La lampe reçoit une puissance égale à sa puissance de fonctionnement normal , elle produit alors un éclair. **(1/2pt)**

1-1) L'aspect corpusculaire. **(1/2pt)**

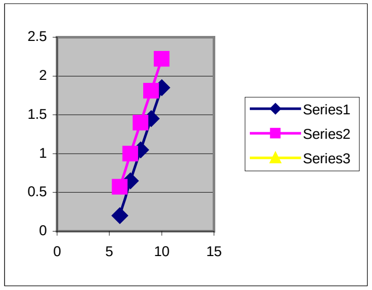
2) masse nulle ; vitesse dans le vide = c ; charge nulle ; énergie = h ν .**(1/2pt)**

3) Lorsqu'un photon, d'énergie h ν , frappe un métal d'énergie d'extraction W_S, il y a émission photoélectrique si h ν est plus grande ou égale à W_S ($\lambda < \lambda_S$ ou $\nu > \nu_S$) **(1/2pt)**

II-1-La relation d'Einstein donne : $h\nu = W_S + E_c$

On peut écrire : $E_c = h\nu - W = a\nu + b$ où a = h et b = $-W_S$ **(1/2pt)**

2- a) Représentation **(1pt)**



b) i- $E_c = f(\nu)$ est une droite ne passant pas par l'origine et de coefficient directeur h.

$$h = \frac{E_{C2} - E_{c1}}{\nu_2 - \nu_1} = \frac{(1{,}85 - 0{,}25)\times 1{,}6.10^{-19}}{10.10^{14} - 6.10^{14}} = 6{,}4.10^{-34}\ \text{J.s}$$ **(11/2pt)**

ii- Si l'électron est extrait avec une vitesse nulle (E_C=0), le métal est éclairé alors par une radiation de fréquence seuil $\nu_S = \frac{W_S}{h}$. La fréquence seuil est l'intersection de la droite obtenue avec l'axe des fréquences. Graphiquement on trouve $\nu_S = 5{,}5.10^{14}$Hz. **(1pt)**

3) On a : $\nu_S = \frac{W_S}{h}$ => $W_S = h\,\nu_S = 6{,}4.10^{-34} \times 5{,}5.10^{14} = 3{,}52.10^{-19}$J = 2,2 eV **(1/2).**

III- 1) pour tracer le graphe du césium, il suffit de placer d'abord le point (7.10^{14}Hz ; 1eV) dans le repère, puis de tracer la parallèle à la droite précédente. **(1/2pt)**

2) Pour déterminer l'énergie d'extraction du césium, il faut prolonger la droite jusqu'à son intersection avec l'axe des E_C ; on trouve W'_S = 1,9 eV. **(1/2pt)**

A- L'énergie consommée par la centrale pendant 1 s est : $\frac{100 \times 3.10^9}{30} = 10^{10}$ W

L'énergie consommée par la centrale pendant 1 jour est :

$E = 10^{10} \times 24 \times 3600 = 864.10^{12}$J. **(1/2pt)**

B - I - La masse de pétrole nécessaire au fonctionnement pendant 1 jour est :

$m_1 = \frac{864.10^{12}}{45.10^6} = 19{,}2.10^6$ kg. **(1/2pt)**

II. 1) L'énergie du neutron est de l'ordre de 0,1 eV (ou neutron thermique ou neutron lent) **(1/4pt)**
.

2) a) L'énergie libérée apparaît sous forme d'énergie cinétique des noyaux et des neutrons. **(1/4pt)**

b) Pour libérer une énergie nucléaire de 189 MeV, on a besoin d'une masse d'uranium égale à 235,04392 u. Pour libérer l'énergie E, on a besoin d'une masse d'uranium $m_2 = \frac{235{,}04392 \times 1{,}66.10^{-27} \times 864.10^{12}}{189 \times 1{,}6.10^{-13}}$ = 11 kg.**(1pt)**

III-1) Les lois de conservation de Z et de A donnent : Z = 0 et A =1 .
La particule est le positon (ou positron). **(3/4pt)**

2) Les noyaux ont une grande énergie cinétique (ou de l'ordre de 0,1 MeV ou température du milieu de l'ordre de 10^8K). **(1/4pt)**

3) L'énergie libérée est donnée par $E_3 = \Delta m.c^2$

$\Delta m = 4 \times 1{,}00728 - 4{,}0015 - 2 \times 0{,}00055 = 0{,}02652$ u

$\Delta m = 0{,}02652 \times 931{,}5$ MeV/c^2 = 24,70338 MeV/c^2.

D'où : E_3 = 24,7 MeV = $39{,}52.10^{-13}$J. **(1pt)**

4) Pour libérer une énergie nucléaire de $39{,}52.10^{-13}$J , on a besoin d'une masse d'hydrogène égale à $4 \times 1{,}00728$ u. Pour libérer l'énergie E, on a besoin d'une masse d'hydrogène

$m_3 = \frac{4 \times 1{,}00728 \times 1{,}66.10^{-27} \times 864.10^{12}}{39{,}52.10^{-13}}$ = 1,5 kg.**(1pt)**

C- $m_3 < m_2 < m_1$: Pour la même production d'énergie, on a une consommation en hydrogène 7 fois plus faible qu'en uranium et 13.10^6 fois plus faible qu'en pétrole.

La fusion ne produit pas des noyaux radioactifs

_ L'hydrogène est plus abondant dans la nature que l'uranium
_ La fusion est plus énergétique que la fission
_ La fusion ne produit pas des gaz toxiques **(1/2pt)**